THE EFFECTS OF FORESTRY MANAGEMENT PRACTICES ON MICROBIAL COMMUNITY PROPERTIES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The structure and function of microbial communities are critical to the maintenance and sustainability of terrestrial ecosystem processes. Consequently, there is substantial interest in assessing how microbial communities respond to various land management practices, and if alterations to the characteristics of microbial communities has the potential to disrupt ecosystem processes. This thesis was conducted to identify the long term effects of fertilisation and different levels of post-harvest organic matter removal on the characteristics of the FH litter and soil microbial communities in six, second rotation *Pinus radiata* plantation forests located around New Zealand.

The six sites, established between 1986 and 1994, were sampled in 2002 and 2003. Various physical and chemical properties of the sites were measured, and litterfall production was determined. The microbial biomass in the FH litter layer and soil was determined by chloroform fumigation-extraction, and Biolog plates were used to assess the relative differences in microbial community diversity, based on patterns of substrate utilisation.

Fertilisation substantially altered the physical and chemical properties of the forest floor, including FH litter moisture content, mass, carbon content, nitrogen content and carbon: nitrogen ratio and soil pH, nitrogen content and carbon: nitrogen ratio. The same range of FH litter and soil properties were also significantly changed by different levels of organic matter removal. The biomass and diversity of the FH litter and soil microbial communities were significantly altered by fertilisation and organic matter removal, and the differences in the microbial community characteristics were significantly correlated to the effects of the fertilisation and organic matter removal treatments on the physical and chemical environment in the majority of cases. The physical and chemical properties of the sites were significantly correlated to estimates of wood production, and it was also found that the characteristics of the microbial community were strongly related to productivity at several sites.

The results demonstrated that fertilisation and organic matter removal regimes have had long term effects on the microbial communities at the sites.

The persistence of the effects of the organic matter removal treatments were particularly noteworthy, as these treatments were applied at site establishment, and despite no subsequent reinforcement over the life of the trials, were still substantially influencing the physical, chemical and microbiological properties of the FH litter and soil up to 17 years later. The results of this thesis also emphasised the value of long-term experiments in assessing the effects of disturbance on the physical, chemical and microbiological characteristics of forest ecosystems. Further research into the specific nature of the relationship between site productivity and microbial community characteristics was suggested as an important focus for future studies.

CHAPTER ONE: INTRODUCTION

The activities of microbial communities are essential to terrestrial ecosystem functions (Kennedy and Gewin, 1997), but only relatively recently have these communities been the focus of detailed research (Wardle and Nicholson, 1996; Hooper *et al*., 2000). The importance of microbial community research has intensified as the potential for anthropogenic activity to disturb the functions of terrestrial microbial communities has been realised (Ajwa *et al*., 1999; Wardle *et al*., 2001). Furthermore, the preservation of native diversity has become a subject of political importance, and has been included in various accords used to regulate land management practices, giving additional prominence to this research (Fox, 2000; Smith *et al*., 2000). Accordingly, it is the aim of this thesis to determine if certain forestry management practices significantly influence the forest floor litter layer and soil microbial communities, and if any alterations to community structure and function are related to alterations in other characteristics of the forest ecosystem.

1.1: MICROBIAL LIFE IN TERRESTRIAL ECOSYSTEMS

Fungal and bacterial life in soil is both abundant and highly diverse. (Torsvik *et al*., 1990), and is comprised of a wide variety of different types of microbe, with an extensive array of capabilities, including numerous plant litter decomposing species known as saprotrophs, bacterial species capable of converting nitrogen gas into ammonia, various types of fungal symbionts, and pathogens which can infect and attack plant life (Tate, 1995). These microbes combine to form what is known as the soil microbial community.

The functions of the soil microbial community are many, varied and critical to terrestrial ecosystem stability (Wardle, 1992; Brussaard *et al*., 1997; Kennedy and Gewin, 1997; Wall and Moore, 1999). Microbial communities are essential to both the initial formation of soil from parent geological materials (Groffman and Bohlen, 1999) as well as the continued maintenance of soil physical structure (Tisdall and Oades, 1982; Miller and Jastrow, 1990), and soil microbial activity is responsible for the production of trace gases that can influence the nature of the atmosphere in and above the soil layer (Mooney *et al*., 1987). Soil microbial communities are also intimately involved with the plant component of terrestrial ecosystems through a number of different processes (Groffman and Bohlen, 1999; Wall and Moore, 1999; Wolters *et al*., 2000), which will be introduced and discussed in later sections.

Despite the importance of the soil microbial community to terrestrial life, and the need to understand the interdependence of above- and belowground ecosystem functions (Bardgett and Wardle, 2003), the ecology and characteristics of soil microbial populations have largely been excluded from the development of ecological theories and plant population models (Zak, *et al*., 1994; Bever *et al*., 1997; Freckman *et al*., 1997; Burrows and Pfleger, 2002; Reynolds *et al*., 2003). This lack of knowledge has generally been attributed to a number of complicating factors hampering the accurate study of soil microbe populations and their activities in the soil environment (Wardle and Giller, 1996; Nannipieri *et al*., 2003). Furthermore, the relationships between soil microbial diversity and soil microbial activity are still a largely unknown quantity (Freckman *et al*., 1997; Schwartz *et al*., 2000). Certain ecosystem functions mediated by the soil microbial community may prove resistant to disturbances despite alterations to microbial diversity, as the presence of a range of species with similar ecological niches can potentially provide a degree of redundancy in the microbial community, resulting in functional stability, which may allow ecosystem function to continue unchanged (Brussaard *et al*., 1997; Chapin *et al*., 1997; Naeem and Li, 1997; Nannipieri *et al*., 2003). Some correlations between diversity and function must exist, however, and this has been linked to the idea of "keystone species" (Wardle and Giller, 1996). These are species which are critical to certain ecosystem functions, such as nitrogen-fixing bacteria, and any alterations to the diversity or functioning of these organisms may result in significant changes to ecosystem function, while alterations to the diversity of species filling a less specific niche – leaf litter decomposers, for example – may have a lesser effect upon the ecosystem functioning as a whole (Chapin *et al*., 1997). However, what are the criteria used to decide what constitutes a "keystone species"? Various species of ectomycorrhizal fungi are common to a wide range of forested soils, but can exhibit significantly different rates of nutrient mobilisation from litter (Bending and Read, 1995). Another technique to simplify the issue may be to divide the microbial community into various functional groups, based on similarities in the activities of the different species, but research based on this methodology may prevent the proper assessment of the actual species diversity within a functional group, masking individual population fluctuations and responses to treatments (Schwartz *et al*., 2000).

Studying the effect of anthropogenic influences upon nutrient pools in managed ecosystems has long been recognised as crucial for the development of sustainable land management practices, in both agriculture and forestry (Jorgensen *et al*., 1975; Coleman, 1989). By calculating the effects of plant material removal upon nutrient reservoirs, and then observing the consequences for ecosystem function, the effects of harvesting on the ecosystem functions of a site can be estimated, and the viability of long term land management practices assessed (Miller, 1963; Weetman and Webber, 1972; Levett *et al*., 1985). More recently, the potential for anthropogenic influences to affect soil microbial community dynamics has also been recognised, and understanding the effects on soil microbial community structure and function is now considered to be equally important to the development of efficient, and sustainable, land management practices in both agricultural and forest based ecosystems (Kennedy and Gewin, 1997; Ajwa *et al*., 1999; Hooper *et al*., 2000, Wardle *et al*., 2001; Harris, 2003; Leckie, 2005). Furthermore, the preservation of native biodiversity and ecosystem stability has become a legal requirement in a number of countries, as the implementation of new laws and the ratification of international treaties has compelled the forestry industry, in particular, to both determine and minimise the ecological effects of management practices (Fox, 2000; Smith *et al*., 2000).

1.2: FUNCTIONS OF MICROBES IN TERRESTRIAL ECOSYSTEMS

1.2.1: Nutrient Cycling

Estimates of global annual net plant primary production in terrestrial ecosystems, defined as the net accumulation of plant biomass (Odum, 1983), vary from 45-65 $\times 10^{12}$ kg of carbon (Schlesinger, 1991), with more recent calculations proposing a figure of 56.4 $\times 10^{12}$ kg for carbon (Beerling and Woodward, 2001). The majority of this production does not remain in the living plant biomass, but becomes litter or is consumed by herbivores (Swift *et al*., 1979; Odum, 1983; Barbour, 1987). Communities of microbial organisms obtain energy and nutrients by processing the litter and organic matter residues into simpler inorganic substances, releasing the nutrients as excrement, exudates or by autolysis. These processes form the basis of nutrient cycling, by which the carbon, nitrogen and other nutrients contained in plant litter are eventually made available to support the nutritional demands of terrestrial vegetation, and is fundamental to the stability and function of all terrestrial ecosystems (Swift *et al*., 1979; Schlesinger, 1991). Numerous species of soil fauna are also important to plant litter decomposition and nutrient cycling (Odum, 1983; Groffman and Bohlen, 1999), and although microbial activity is reported to be responsible for 90-95% of nutrient mineralisation from organic plant litter in a range of ecosystems (Swift and Anderson, 1993), soil animals facilitate litter decomposition by physically shredding and mixing organic matter, processing it into forms more readily susceptible to microbial degradation (Freckman *et al*., 1997; Cragg and Bardgett, 2001; González and Seastedt, 2001). The excrement of larger soil animals, such as earthworms, can provide microhabitats that accelerate the catabolism of organic litter by the microbial community (Edwards *et al*., 1995), and it has also been reported that conditions in the foregut of some tropical earthworm species enhances the rate of nutrient mineralisation from consumed organic matter (Brussaard *et al*., 1997, Doube and Brown, 1998). Nutrient cycling is also influenced by the functions of soil fauna, as many species, such as protozoa (Sleigh, 1989), collembola (Hanlon and Anderson, 1979) and nematodes (Ferris *et al*., 1998; Chen and Ferris, 1999) feed on soil microbes, acquiring nutrients from the soil microbial biomass, eventually returning them to the soil as waste excretions or upon death (Anderson *et al.*, 1981). Even though the soil microbial community has been considered as the principle component in plant litter degradation and nutrient cycling (Coleman and Crossley, 1996, Kennedy and Gewin, 1997), because of the influence of soil animals, these processes have often been considered in terms of the total soil biota (Brussaard *et al*., 1997; Bever *et al*., 1997; Groffman and Bohlen, 1999).

Nutrient cycling is not totally mediated by the soil biota, however, as nutrient release from plant litter can also occur abiotically via the leaching of water-soluble substances. Depending upon the plant species and types of litter (Berg and Staaf, 1981), these leachates can contain large concentrations of readily accessible carbon, nitrogen and other essential elements, and have been reported to account for up to 24% of dry litter mass in some cases (Nykvist, 1959). Leaching is also dependent upon the presence of water, so rainfall and other factors involved in regulating litter layer moisture levels are important to determining the significance of leaching in an ecosystem (Berg and Staaf, 1981).

1.2.2: Mycorrhizal Associations

A wide range of fungal species can interact even more directly in plant nutrition through the formation of symbiotic associations with plant roots. These species, termed mycorrhizal fungi, are found in association with almost all plant species in nature (Smith and Read, 1997), and the majority of woody plant species are dependent on mycorrhizal associations for nutrient acquisition (Trappe, 1979). Mycorrhizal species are classified by the physical nature of the association formed with host plants (Marks and Kozlowski, 1973; Sanders *et al*., 1975), and the two major categories are defined as “Sheathing” and “Endo” (Read, 1998). Sheathing mycorrhizal fungi form dense sheaths of fungal tissue around infected plant root tips, and can alter the morphology of the epidermal root cells, resulting in the formation of a structure known as the Hartig net (Isaac, 1992). The sheath and Hartig net are connected to networks of hyphae, extending out into the soil (Marschner, 1995). Endomycorrhizal species do not form sheaths around infected roots, instead directly penetrating the tissue of infected roots (Read, 1998). The association between mycorrhiza and plant can be mutually beneficial to both, as the fungi can assimilate carbon from molecules exuded by the plant root cells, while the hyphal network supplies inorganic nutrients such as phosphorous and nitrogen to the plant, effectively increasing the below ground surface area available for nutrient acquisition from decomposing plant litter and soil (Bottner *et al*., 1984; Bolan, 1991; George *et al*., 1995). However, plant growth responses resulting from plant-mycorrhizal associations can vary significantly, based on the combination of plant and fungal species, from highly mutualistic to highly parasitic, indicating that some association combinations can "cost" the plant species in question more than it gains (Streitwolf-Engel, 1997; van der Heijden *et al*., 1998a; Klironomos, 2003). Some mycorrhizal associations have also been reported to confer additional benefits, such as increased resistance to pathogens and drought (Burrows and Pfleger, 2002; Reynolds *et al*., 2003). In a field trial Newsham *et al.* (1995) determined that a species of annual grass was significantly less susceptible to infection by a known pathogen following inoculation with mycorrhizal fungi. In another study, pepper plants inoculated with mycorrhizal fungi were found to be capable of acquiring more moisture from soil than uninoculated plants, when growing in water-limited conditions (Davies *et al*., 1993). Mycorrhizal associations have also been found to increase the lifespan of colonised roots, although this was not observed to occur with all host plants species studied (Atkinson *et al*., 2003).

1.2.3: Plant Growth Promoting Bacteria

The formation of beneficial associations between microbes and plants is not limited to fungal species. A number of bacterial species, termed Plant Growth Promoting Bacteria (PGPB), can also encourage the establishment and growth of host plant species (Leong, 1986; Schippers *et al*., 1987, Kloepper *et al*., 1989). Perhaps the best, and oldest, known examples of PGPB are the nitrogen-fixing bacteria. A number of bacterial species are capable of reducing nitrogen gas into ammonia, in an enzymatic process called nitrogen fixation (Sprent, 1987; Tamm, 1991). Various species of nitrogen-fixing bacteria are also able to infect the root hair tissue of a range of plant species, and induce the development of nodules through the secretion of chemical signals to the host plant, which the bacteria then colonises (Ljunggren, 1969; Bond, 1970). The bacterial colony benefits from this symbiosis by acquiring carbon compounds and other nutrients from the colonised plant, and secretes excess fixed nitrogen to the plant in return (Sprent, 1987). Although the plant must “pay” for both the development of nodules and the ongoing nutrient requirements of the bacterial colony, the benefits of an increased, sustained supply of accessible nitrogen outweigh these burdens (Boddey *et al*., 1997), while colonisation by nitrogen-fixing bacteria may also provide protection against pathogenic microbes (Reynolds *et al*., 2003). A significant number of nitrogen-fixing bacterial species, termed free-living, do not form associations with plants, and these bacteria tend to be carbon-limited and generally fix nitrogen at a slower rate than symbiotic bacteria, with the exception of phototrophic species (Postgate, 1987). Nitrogen fixation is also vital to the long term global nitrogen cycle, as it is the only natural mechanism for the conversion of significant quantities of inert nitrogen gas into biologically accessible forms (Söderlund and Svensson, 1976; Tamm, 1991). Other types of PGPB perform further beneficial functions, such as acting as biological control agents by reducing populations of pathogenic soil microbes (Weller, 1988; Boelens *et al*., 1994), synthesising phytohormones to stimulate plant growth (Dobbelaere *et al*., 1999; Kloos *et al*., 2001; Riggs *et al*., 2001; Bai *et al*., 2003) and producing siderophores to solubilise and sequester iron from soils, potentially allowing increased plant growth in soil contaminated with heavy metals or other toxic xenobiotics (Burd *et al*., 2000; Glick, 2003). Certain species of PGPB also improve the ability of plants to acquire nutrients from soil, particularly phosphorous (Rodriguez and Fraga, 1999; Egamberdiyeva and Hoflich, 2003).

1.2.4: Pathogenic Microbial Associations

Pathogenic microbial species influence plant communities by decreasing the fecundity and survival rates of susceptible plant species, causing a reduction in competition for the resistant plants in the community, potentially resulting in changes to the diversity and successional development of plant biomass an ecosystem (Augspurger, 1988; Bazzaz, 1996; van der Putten, 2003). Some soil microbial pathogens are so effective they can kill all susceptible plants, and continue to survive by acquiring nutrients from the dead plant biomass (Jarosz and Davelos, 1995; Packer and Clay, 2000), while the development of communities of specific soil microbial pathogens is the driving factor behind the rotation of crops in agroecosystems (Reynolds *et al*., 2003). However, as climatic conditions and the presence or absence of other microbial species are significant factors in determining the effectiveness of several major groups of pathogens, the extent of the effect of pathogenic microorganisms is strongly influenced by local ecosystem conditions (Lavelle and Spain, 2001; Reynolds *et al*., 2003).

1.2.5: Regulation of Plant Population Dynamics

The relationship between the soil microbial community and the plant community is so fundamental that it has been suggested that the characteristics of the soil microbial community significantly influence the evolution and population dynamics of natural plant communities through regulation of plant nutrition and the formation mutualistic and pathogenic relationships (Bever, 1994; Watkinson, 1998, Wall and Moore, 1999; Klironomos, 2002). A relationship between belowground mycorrhizal species diversity and aboveground plant communities has been described by Grime *et al*. (1987), reporting that the presence of a mycorrhizal fungus resulted in increased floral diversity in microcosms, while field experiments in prairie and grassland sites have indicated that plant species can react differently to microbial symbiosis (Hartnett *et al*., 1994), potentially to the point where belowground mycorrhizal diversity may drive aboveground plant diversity by promoting growth in some plant species over others (van der Heijden *et al.*, 1998a). The question of whether or not plant diversity can be directly related to mycorrhizal diversity, in terms of purely the numbers of species present, is contentious, however (Hooper *et al*., 2000).

1.3: RESEARCH INTO SOIL MICROBIAL COMMUNITY AND ECOSYSTEM FUNCTIONS

Many factors have caused the relative paucity of research into the ecology and functions of the soil microbial community. The first of these, as identified by Wardle and Giller (1996), is the tendency to focus on the more visible, and possibly more appealing, components of ecosystems, such as mammalian and avian life. Initial attempts to investigate the range of microbial species present in soil using conventional culture-based methods have been hampered by the presence of viable but non-culturable soil microorganisms, preventing the study and identification of all but a fraction of microbes found in soil, with no indication as to the relative importance and functions of the species that can be successfully identified (Perfilev and Gabe, 1969; Bakken, 1985; Tunlid and White, 1992). Furthermore, the high levels of physical complexity and diversity in soil conditions result in the formation of a wide range of microhabitats, occupied by an equally diverse range of microbial species, confounding attempts to determine the range and spatial variability of soil microbe species (Parkin, 1993; Ohtonen *et al*., 1997), and continuously revised taxonomic systems complicate the matter even further (Freckman *et al*., 1997). Finally, the scale of soil microhabitats makes it difficult to study soil microbes *in situ* without disrupting the native conditions, and due to the rate of microbial turnover and reproduction, potentially the composition of the microbial community itself (Groffman and Bohlen, 1999), while the “opaque” nature of soil further complicates *in situ* studies (Wardle and Giller, 1996; Freckman *et al*., 1997).

The introduction and establishment of new analytical techniques, combined with an increased interest in understanding and preserving the biodiversity of natural ecosystems (Wardle and Nicholson, 1996; Hooper *et al*., 2000), has allowed an expansion of research into the diversity and activity of soil microbial communities in a range of environments (Borneman *et al*., 1996; Kennedy and Gewin, 1997; Reynolds *et al*., 2003). Innovations in culturing techniques have increased the range of microorganisms able to be isolated and grown in laboratories (Tiedje and Stein, 1999), while substrate utilisation has been used to characterise microbial communities, based on the range of molecules and compounds the microbial species present are capable of catabolising (Garland and Mills, 1991; Haack *et al*., 1995; Stevenson *et al*., 2004). Lastly, the development and widespread adoption of molecular techniques, based on the detection and identification of phospholipid fatty acids (Vestal and White, 1989; Frostegård *et al*., 1993a) and genetic material in polymerase chain reactions (PCR) and other nucleic acid based methods (Torsvik *et al*., 1990; Borneman *et al*., 1996; Nakasu *et al*., 2000), have revolutionised the direct assessment of microbial community diversity in a soil at a given point in time. Molecular methods for assessing diversity do have some disadvantages, however, as nucleic acids extracted from soils can be contaminated with humic and polyphenic substances which inhibit PCR (Kuske *et al*., 1998; Vettori *et al*., 1999). Furthermore, the PCR process can produce artefacts, and can also be biased to select for particular genetic sequences, potentially compromising the veracity of results (Kennedy and Gewin, 1997; Ogram, 2000). It has also been suggested that the safest and most reliable technique to quantify soil microbial community diversity is to use a combination of methods, based on variations in the results of phospholipid fatty acid, nucleic acid and substrate utilisation based methods employed on the same soils (Widmer *et al*., 2001). Techniques enabling the analysis of soil microbial community functions have similarly been developed and improved, including the detection of specific microbial enzymes (Sinsabaugh *et al*., 1991), the rate of fluoresecin diacetate (FDA) hydrolysis by the microbial community in soil samples (Schnürner and Rosswall, 1982; Adam and Duncan, 2001) and the use of radio-labelled and naturally occurring isotopes to track the flux of nutrients through soil microbial biomass (McGill *et al*., 1975; Chauhan *et al*., 1979; Kuzyakov *et al*., 2000).

Since their introduction, the advances discussed above have allowed the characteristics of a range of natural microbial communities to be investigated, facilitating the formation of new theories regarding the interactions between plants, soil, and the soil microbial community in undisturbed conditions (Kennedy and Gewin, 1997). Parameters of microbial community structure that have been examined in undisturbed ecosystems include soil microbial biomass (Fritze *et al*., 2000; Franzluebbers *et al*.,

2001) and community diversity (Garland and Mills, 1991; Dunbar *et al*., 2000; Poly *et al*., 2001), while microbial community function has been examined utilising enzyme activity assays (Colpaert and Laere, 1996; Dilly *et al*., 2001). Although this research does provide valuable “baseline” information regarding natural patterns of biogeochemical cycling (Hedin *et al*., 1995), it has been suggested that research into how soil microbial communities react to anthropologically induced influences and disturbances is of greater importance, with the potential to improve long term land management practices and strategies by more accurately accounting for the effects of microbial communities on nutrient cycling pathways in terrestrial ecosystems (Parkinson and Coleman, 1991; Wardle and Giller, 1996; Kennedy and Gewin, 1997; Groffman and Bohlen, 1999; Adams and Wall, 2000). Disturbances to natural environments, resulting from both planned land management practices or unintentional side effects of human activities, such as pollution and urban spread (Pang and Kolenko, 1986; Findlay and Jones, 1990; McDonnell and Pickett, 1990; Markkola *et al*., 1995), have the potential to change conditions in the soil and ecosystems as a whole, potentially leading to alterations in the microbial community structure through shifts in selection pressures (Kennedy and Gewin, 1997). Any alterations in the biomass and/or diversity of the microbial community may then impact upon the soil processes and plant interactions mediated by microbial activity, depending upon if, or how, the microbial species involved in these processes have been affected (Wardle and Giller, 1996; Ohtonen *et al*., 1997; Wall and Moore, 1999).

1.4: EFFECTS OF DISTURBANCES ON THE SOIL MICROBIAL COMMUNITY

In the literature there are now a number of examples and discussions of the potential and known effects of various treatments or events, either natural or anthropogenic in origin, upon soil microbial community structure and activity. Despite this, however, the significance of the effects of a number of factors remains unclear, as in many cases inconclusive or contradictory results have been produced (Wardle, 1992). Furthermore, a significant proportion of the research that has been performed has been focused on assessing the effects of disturbances in agroecosystems, and consequently considerably less is known about the effects of disturbances on the soil microbial community in other types of ecosystem (Johnson *et al*., 2003).

1.4.1: Nutrient Amendment

Nutrient additions increase the amount of available nutrients in soils, and can also alter other soil parameters, such as decreasing the soil pH (Ballard, 2000; Smethurst *et al*., 2001), and consequently there has been interest in relating nutrient amendment to soil microbial properties. A number of studies have determined that the addition of mineral nitrogen to soils in agricultural systems resulted in increased soil microbial biomass (Schnürer *et al*., 1985; Shen *et al*., 1989; Insam *et al*., 1991), but in many other investigations the response of the soil microbial community to nitrogen addition in agricultural soils and residues has been reported to vary significantly, in some cases influenced by the amount of nitrogen added, but varying idiosyncratically in others (Carter, 1986; Sparling and Williams, 1986; van de Werf and Verstraete, 1987; Bonde *et al*., 1988; Ocio *et al*., 1991). Nitrogen dominated fertiliser amendments in a *Pinus sylvestris* L. forest ecosystem were also observed to significantly decrease soil microbial biomass, based on measurements of FDA hydrolysis (Bååth and Söderström, 1982), while nitrogen addition to a range of coniferous forest soils resulted in significantly decreased soil microbial respiration and biomass (Söderström *et al*., 1983). However, Ohtonen *et al*. (1992) found that although fertiliser addition decreased soil microbial biomass in terms of carbon content, it had no effect when determined by the nitrogen content of the microbial biomass, simultaneously agreeing and disagreeing with the previous studies.

The application of new techniques in recent studies has not readily fixed the problem of contradictory results. Peacock *et al*. (2001) found that the application of ammonium nitrate over five years had no significant effect upon soil microbial biomass, but did induce a significant shift in soil microbial community structure, based on polar lipid fatty acid profiles extracted from the 0-5cm deep soil layer. Contradicting this, Sarathchandra *et al*. (2001) found that the addition of nitrogen to soil over several years in the form of urea - in amounts equivalent to those employed by Peacock *et al*. (2001) - resulted in no detectable changes to the diversity of the soil microbes, based on culturing methods. Another study, focusing on ectomycorrhizal diversity in *Picea abies* forest soil treated with nitrogenous fertiliser, found no detectable alteration to the species diversity, although fungal sporocarp production and diversity was significantly reduced (Jonsson *et al*., 2000). In a separate study, again based in a *Picea abies* forest, it was similarly concluded that nitrogen addition resulted in a decrease in the diversity of fungal sporocarps, but below-ground ectomycorrhizal diversity was significantly decreased in this case (Peter *et al*., 2001). This variation in the responses of the microbial community to nitrogen amendment is consistent with those reported previously by Wardle (1992), and indicates that soil microbial community response may be dependent upon factors such as soil pH and soil nutrient contents, as well as the initial characteristics of the soil microbial community itself (Lee and Jose, 2003).

The application of organic materials to soils can also influence the soil microbial community. The application of manure, either green or farmyard, and sewage sludge can cause significant increases in crop production, and is employed on a long term basis in many agroecosystems (Edmeades, 2003). The effect of these additions on the soil microbial community has been the focus of several studies, and it is generally held that organic amendments increase soil microbial biomass, and can also increase microbial enzymatic activity and significantly alter species diversity (Ritz *et al*., 1997; Peacock *et al*., 2001; Poll *et al*., 2003; Speir *et al*., 2003).

1.4.2: Forest Harvesting Operations

Forest harvesting strategies can vary significantly, and result in different levels of nutrient removal, harvest residue retention and physical disturbance in the forest floor litter layer and soil (Jorgensen *et al*., 1975; Bååth, 1980; Ohtonen *et al*., 1992). Increasing levels of organic matter removal during harvest have been reported to cause decreased soil nutrient concentrations in some circumstances, decreased soil solution pH and increased variability in soil and litter temperature and moisture levels, and consequently has the potential to influence microbial community properties

(Bååth, 1980; Ballard, 2000; Bock and Van Rees, 2003; Li *et al*., 2004). Clear felling also been found to produce a significant reduction in fungal biomass and activity in the harvested area (Bååth, 1980; Mah *et al*., 2001). It has been suggested that this effect may be alleviated by partial felling, where only a percentage of trees are felled. This is based on an eight year trial in a mixed western hemlock – western redcedar forest, where ectomycorrhizal fungal diversity was not significantly altered after partial felling had occurred (Kranabetter and Kroeger, 2001). Tree harvesting is often associated with erosion and soil compaction, as the operation of heavy machinery and the road construction required may lead to significant alteration of the soil surface and conditions (Briggs *et al*., 2000; Lacey and Ryan, 2000), and soil compaction in particular has been linked with significant decreases in soil and microbial biomass and enzymatic activity (Amaranthus *et al*., 1996; Vance and Entry, 2000), although this is not always observed (Chen *et al*., 2003).

1.4.3: Physical Modification of Litter Layer and Soil Surface

Soil surface modification practices in agroecosystems, such as the mixing of organic litter and the upper soil layers through conventional tilling and ploughing regimes, have been found to decrease soil microbial biomass compared to untilled fields (Doran, 1980; Frey *et al*., 1999; Guggenberger *et al*., 1999; Drijber *et al*., 2000). Ploughing is also used as a forestry management practice in some circumstances to prepare a site for the next crop of trees, and has similarly been found to decrease soil microbial biomass during the growth of the subsequent rotation at the site (Chen *et al*., 2003). The amount of organic matter present on the forest floor has been also linked with the functional diversity of the soil microbial community, based on chronosequence studies, correlating the accumulation of organic matter over time with the characteristics of the soil microbial community (Tscherko *et al*., 2003). However, not all such disturbances may have an effect, as the removal of the soil surface organic matter (scarification) prior to the planting of *Pinus strobus* L. in a plantation forest has been reported to have no effect on soil microbial biomass five years after the scarification occurred (Ohtonen *et al*., 1992).

1.4.4: Exposure to Xenobiotics and Heavy Metals

The exposure of terrestrial ecosystems to substances not previously encountered by the biota of that environment (xenobiotics) has become a common occurrence due to anthropogenic practices, and this can have various unpredictable effects upon biotic communities and the processes they are involved in (Francis, 1994). Herbicide application is utilised to kill plant biomass, but herbicides have also been found to have direct effects on soil microbial community structure (Ohtonen *et al*., 1992; Seghers *et al*., 2003), as well as possible secondary effects relating to alterations to plant biomass, which will be discussed in more detail later. Studies assessing the effects of several pesticides on soil microbial community structure in short and long term field studies suggest that pesticide applications may decrease soil microbial biomass and diminish the diversity of the soil microbial community, but few significant effects in field studies have been reported to date (Bromilow *et al*., 1996; Taiwo and Oso, 1997; Ahtiainen *et al*., 2003).

The contamination of soil with compounds such as polyaromatic hydrocarbons (Nakatsu *et al*., 2000), heavy metals (Frostegård *et al*., 1993b; Perkiomaki *et al*., 2003) and other types of xenobiotic (Soltmann *et al*., 2002) have also been found to alter microbial community structure when compared to undisturbed soils and litter layers, by providing an additional community selection pressure based on tolerance to the xenobiotic (Richter *et al*., 2003). Additionally, heavy metals have been found to influence the enzymatic activity of soil microbial communities, potentially altering ecosystem functions mediated by those enzymes (Brohon *et al*., 2001; Smejkalova *et al*., 2003). In recent years, research into how microbial communities react to various xenobiotics has taken on new meaning, as this research may lead to the identification of microbial species capable of not only tolerating xenobiotic compounds, but also capable of degrading or sequestering xenobiotics, with potential applications in the restoration of contaminated ecosystems to pre-disturbance states (Rieger *et al*., 2002).

1.4.5: Functions and Potential Effects of Alteration to Plant Community Structure

Disturbances and alterations to the diversity and structure of plant community merit particular attention, as plant communities themselves are primary drivers of a number of important ecosystem functions (Dickinson and Murphy, 1998). Plant communities are critical to the fixation of atmospheric carbon dioxide and the global carbon cycle (Smith *et al*., 1993; Naeem *et al*., 1994), and can also buffer the effects of water stress on ecosystem function (Tilman and Downing, 1994). Plant community species composition influences nutrient cycling, and has been correlated with the levels of primary production and inorganic nitrogen uptake from soils in several studies (Hooper and Vitousek, 1997, 1998; Grime, 1998), although not all results are consistent (Jollife, 1997; Wardle, 1999). Plant communities also significantly influence the belowground environment, as individual plants have the capacity to alter local conditions through a variety of mechanisms (Casper *et al*., 2003; Paterson, 2003), which can in turn influence the belowground microbial community (Bever *et al*., 1997; Reynolds *et al*., 2003). Consequently, alterations to the biomass and the diversity of the plant community have been found to have belowground feedback effects, resulting in changes to the structure of the soil microbial community (Hooper *et al*., 2000, Wardle *et al*., 2001; Tscherko, 2003).

These alterations to the soil microbial community have been found to occur through several mechanisms. Virtually all soil microbial communities ultimately depend on plants for carbon (Johnson *et al*., 2003), and as different plant species produce varying quantities and qualities of aboveground litter and belowground root litter and exudates, alterations in the type and nature of this organic material made available to the soil microbial biomass can alter which microbial species are present, and the proportion of the total biomass they represent (van Veen *et al*., 1989; Wheatley *et al*., 1990; Lindquist *et al*., 1999; Hooper *et al*, 2000). This is of particular importance in ecosystems where the native vegetation has been cleared or significantly reduced, as this may prompt radical alterations to the soil microbial community structure (Hooper *et al*., 2000, Wardle *et al*., 2001). Conversion of land from natural vegetation to arable crops has been found to result in decreased soil microbial biomass, in tropical forests (Ayanabe *et al*., 1976; Srivastava and Singh, 1991) and grasslands (Lynch and Panting, 1980). Specific components of the microbial community may also be affected, such as mycorrhizal fungi, which are strongly influenced by the composition of the host plant community, so alterations to the plant species present may change the composition of the mycorrhizal community (Johnson *et al*., 1992, Eom *et al*., 2000), while forestry practices resulting in even-age stands in monoculture plantations have been found to influence mycorrhizal species diversity and biomass when compared to mixed age stands (Rao *et al*., 1997; Smith *et al*., 2002, Cullings *et al*., 2003). The introduction of plants capable of forming associations with non-native species of microbes, such as mycorrhizae or nitrogen-fixing bacteria, can also change the soil microbial community, as it provides new habitats for non-native microbes, which may then have implications for ecosystem function (Kass *et al*., 1997). Lastly, it has also been suggested that plants may be able to influence microbial gene expression through the production and secretion of specific chemical signals in root exudates, potentially activating or suppressing an activity in a receptive species of microbe (Paterson, 2003).

1.5: DISTURBANCE, SOIL MICROBIAL COMMUNITIES AND LONG TERM SOIL SUSTAINABILITY AND PRODUCTIVITY

Although it is known that the soil microbial community can respond very rapidly to a number of anthropogenic disturbances (Wardle, 1992), there is a need to determine the long term effects of disturbances on soil conditions, biotic communities, functions and productivity (Kennedy and Gewin, 1997; Hooper *et al*., 2000, Wardle *et al*., 2001). A number of long term agricultural field experiments have been established, most notably the Broadbalk Continuous Wheat Experiment plots at Rothamsted, which have been under continuous treatment and study since establishment in the 1840's (Jenkinson and Rayner, 1977). Some investigations of the effects of the management practices on the soil microbial community have been performed at the Broadbalk plots, assessing the pools and flux of nutrients through the soil microbial biomass (Jenkinson and Parry, 1989; Shen *et al*., 1989). The effects of fertiliser additions and other management practices on the soil microbial biomass at Rothamsted, when compared to untreated and unmanaged plots of land, has also been examined, (Bromilow, *et al*., 1996; Glendining *et al*., 1996; Hargreaves *et al*., 2003). However, the original focus of this and other long term agricultural study sites has been directed overwhelmingly towards determining the effects of agricultural management practices on meeting the nutritional demands of continuous crop production (Jenkinson, 1991; Vance, 2000), and more recently at Rothamsted, effects on nutrient flux, crop yields and crop nutrient characteristics from one rotation to the next (Glendining *et al*., 2001; Edmeades, 2003; Brentrup *et al*., 2004; Lopez-Bellido *et al*., 2004).

Conversely, many studies that focus on examining the soil microbial community look at the effects of a continuous disturbance, or do not make repeated measurements following disturbance, and therefore little is known about the ability of soil microbial communities to return to pre-disturbance states following a disturbance event, defined as the resilience of the community (Klein and Paschke, 2000; van Bruggen and Semenov, 2000; Westergaard *et al*., 2001). Some biotic components of ecosystems may also react more slowly to disturbances, preventing short term experiments from detecting gradually developing effects upon the population and distribution of those species, and potentially the ecosystem functions they mediate (Morris and Miller, 1994; Tilman *et al*., 1994).

Chronosequences and retrospective studies can be employed to make assessments of long term effects, and although these research strategies do offer some advantages, usually in terms of time frame and cost, but the inability to control the initial conditions, the potential for heterogeneous influence by external factors and lack of repeatability can significantly confound any results unless study sites are carefully controlled and monitored (Dyck and Cole, 1994; Yanai *et al*., 2000). Additionally, studies into the effects of land management on the soil biota have tended to focus on only one type of disturbance, and/or measure the response in terms of a specific function or group of organisms (Wardle *et al*., 2001). A strong need exists to perform studies incorporating as many relevant disturbance regimes and ecosystem responses in combination as possible, to enable a more holistic, and realistic, approach to long term modelling and planning sustainable land use (Kimmins, 1994; de Ruiter *et al*., 1995; Vitousek *et al*., 1997).

Research into the long term effects of anthropogenic influences may allow predictions of how microbial communities will react to future stresses and disturbances, enabling land managers to potentially preserve or restore microbial diversity, minimise any negative effects on ecosystem function, and encourage desired effects (Bentham *et al*., 1992; Kennedy and Gewin, 1997). Some of the benefits that have been suggested include improved crop production and soil health (Kennedy and Gewin, 1997) and an improved ability to maintain populations of key beneficial microbial species, such as nitrogen-fixing bacteria (Wei and Kimmins, 1998) and mycorrhizal fungi (van der Heijden *et al*., 1998b). One of the greatest benefits may be in the field of sustainable forestry practices, where an understanding of how conventional forestry land management strategies affect long term soil microbial community structure and function could be used to increase the efficiency and productive lifespan of established plantation forest soils, decreasing the need to convert additional land to forests (Noble and Dirzo, 1997; Cline *et al*., 2006).

1.6: SUSTAINABLE FORESTRY MANAGEMENT

Forests are subjected to many forms of natural disturbance, such as wildfires, earthquakes and windstorms, but the most common and most intensive disturbance to many forests result directly from silvicultural activities (Kimmins, 1994), such as nutrient losses through harvesting, erosion, alterations to soil chemical and physical characteristics, as well as changes to the quantity and quality of plant litter (Worrell and Hampson, 1997; Grigal, 2000). Although the concept of sustainability in forestry has been recognised for many decades (Goodland, 1995), in terms of planning and management practices it has been limited primarily to the maintenance of timber yields from successive rotations (Beets *et al*., 1994; Thomas *et al*., 1999), as well as minimising and remediating nutrient losses resulting from harvesting and leaching (Jorgensen *et al*., 1975; Johnson, 1994; Richter *et al*., 2000) and attempts to regulate soil fertility (Kimmins, 1996). Similarly, the effects of physical soil alteration upon forest productivity are comparatively well understood (Worrell and Hampson, 1997), but the short and long term effects upon forest productivity of alterations to soil chemical and biological properties has not been investigated as thoroughly, and are consequently less well documented (Grigal, 2000).

As a result of this narrow view, sustainable forestry models that have been generated based principally on continuous timber production have been subject to criticism for ignoring the inputs and effects of other components and functions of forest ecosystems, both short and long term in nature (Resources Assessment Commission, 1991; Goodland, 1995; Richardson *et al*., 1999). Furthermore, the adoption of a range of national and international agreements focusing on sustainable forestry management, such as the Montreal Process (Anonymous, 1995), has advanced the issue, requiring the effects of forestry management practices upon a much wider range environmental criteria to be assessed, and if necessary, acted upon (Fox, 2000), while national and international bodies continue to determine and refine the most appropriate criteria, indicators and methodologies for sustainability (Smith *et al*., 2000; Ministry of Agriculture and Forestry, 2002).

This has culminated in the need to expand the definition and practices of sustainability in forestry to include the conservation of biological diversity, be it plant, animal or microbial, and the preservation of ecosystem functions and processes for both future rotations and alternative land uses (Noble and Dirzo, 1997), by conducting studies that assess the effects of a wider range of anthropogenic disturbances, encompassing an equally expanded array of relevant biotic and abiotic ecosystem responses (Kimmins, 1996; Namibar, 1996; Worrell and Hampson, 1997; Richardson *et al*., 1999).

1.7: AIMS AND FRAMEWORK OF THESIS

1.7.1: Rationale for Performing Study in Plantation Forestry

This study is being conducted in a forestry setting for a number of reasons, but primarily because it is possible to examine long term effects of management practices at the selected sites, which, as discussed above is currently a research priority (Wolters *et al*., 2000; Wardle *et al*., 2001). Although it is possible to find agricultural sites with well-documented histories of management treatments, it is not possible to study the sites for more than a few months before disruption begins again, due to the "periodic and chronic disturbances inherent in agricultural management" (Elliott and Cole, 1989). Plantation forests offer the opportunity to study the effects of a disturbance event on soil conditions, nutrient cycling and biotic communities, as well as the characteristics of the trees themselves for several decades, before the next cycle of disturbance resulting from harvesting and site preparation for the next rotation.

A second reason for this study to focus on plantation forestry is the importance of this industry to New Zealand, and lastly the current international political climate regarding the maintenance of ecosystem functions and biodiversity. Exotic forest estates in New Zealand occupy 1.6 million hectares, or approximately 6% of the total land area, and yield over 98% of total forest production in New Zealand (Ministry of Agriculture and Forestry, 1998). In 1997, the export of forest products from this production accounted for 11% of the total export earnings of New Zealand (Smith *et al*., 2000). Globally, wood use in 2000 has been estimated at 3.5 billion m^3, and is estimated to increase by 300 million m^3 by 2010, while global forest area is anticipated to decrease by 200 million hectares in the same period (Fox, 2000). This disparity is likely to both increase the value of wood, and the pressure to maximise yields from remaining forest holdings to meet increased demands, including those in New Zealand (Smith *et al*., 1994; Wienand and Stock, 1995). Due to environmental legislation requiring the preservation of native forests (Ministry of Forestry, 1994), the New Zealand forestry industry is already heavily dependent upon a comparatively small land area for production, and pressure to increase yields from this land may intensify the effects of forestry management on the ecosystem.

Furthermore, New Zealand is a signatory to the Santiago Declaration, which endorses the terms of the Montreal Process (Anonymous, 1995), and has been ratified by countries holding over 90% of the total remaining temperate and boreal forests (Richardson *et al*., 1999; Brockerhoff *et al*., 2001). The Montreal Process outlines a number of criteria that need to be addressed in forest management, including the maintenance of biodiversity, maintenance of forest ecosystem productive capacity, health and vitality, soil and water conservation, forest contributions to global carbon cycles and socio-economic benefits. Internationally agreed upon parameters for productive capacity include forest area, stocking, growth and yield, while soil conservation is to be measured by levels of erosion, soil organic matter and chemical properties, soil physical properties and accumulation of toxic substances, but parameters for the other criteria have yet to be universally established, and are under discussion (Smith *et al*., 2000). In New Zealand, the preservation of large areas of native forest has satisfied several requirements of the Montreal Process, but other issues, particularly regarding the preservation of biodiversity within plantations, require long term research to enable the New Zealand forestry industry to both meet the terms of the Montreal Process and to alleviate political and public concerns (Brockerhoff *et al*., 2001). As the soil microbial community constitutes part of the total genetic diversity of forestry plantations, as well as underpinning numerous ecosystem functions also included in the Montreal Process, studying the effects of forestry management on the microbial community takes on even more relevance to the construction of long term sustainable forestry management models (Brussaard *et al*., 1997; Kennedy and Gewin, 1997; Noble and Dirzo, 1997; Wall and Moore, 1999).

1.7.2: Thesis Hypotheses and Research Structure

This need to examine more aspects of ecosystem diversity and function leads to the aim of this thesis – to test the hypotheses listed below, with the intention of determining whether a range of conventional forestry management practices have substantially altered the environmental conditions and microbial community in the forest litter layer and soil, and the potential implications of any changes for productivity and long term sustainability of the forest.

1. **Fertilisation and organic matter removal have altered the physical and chemical environment in the litter layer and soil at a range of sites.**

Fertiliser additions were expected to increase nutrient concentrations in the litter layer and soil, increase litter accumulation and decrease soil pH, as described in the literature (Wienand and Stock, 1995; Nohrstedt, 2001). Increasing levels of organic matter removal were anticipated to produce decreased nutrient availability, moisture content and litter layer mass, as reported previously (Bååth, 1980; Skinner *et al*., 1989; Ballard, 2000).

2. **Fertilisation and organic matter removal have produced variations in microbial community properties at the sites, resulting from the changes in the physical and chemical environment produced by the fertilisation and organic matter removal.**

Fertilisation was predicted to decrease the microbial biomass, and to alter the relative species composition of the microbial community, as has been reported in several studies (Bååth and Söderström, 1982; Söderström *et al*., 1983; Peter *et al*., 2001) although it was noted that these responses have not been uniformly observed (Wardle, 1992). Microbial biomass was anticipated to decrease with increasing levels of organic matter removal, as discussed earlier (Amaranthus *et al*., 1996; Vance and Entry, 2000, Mah *et al*., 2001), and the structure of the microbial community was expected to change as well, based on other studies (Tscherko *et al*., 2003; Li *et al*., 2004).

For both fertilisation and organic matter removal, it was anticipated that any significant responses in the microbial community properties could be statistically related to the effects of fertilisation and organic matter removal on the physical and chemical environment at the sites.

3. **Fertilisation and organic matter removal have altered the productivity of the sites, and the variations were related to the effects of fertilisation and organic matter removal on the physical, chemical and microbiological characteristics of the sites.**

Fertilisation was anticipated to increase the productivity of the sites, and increasing organic matter removal was anticipated to decrease site productivity, due to the effects of the treatments on nutrient pools and availability (Jorgensen *et al*., 1975; Beets *et al*., 1994; Johnson, 1994; Richter *et al*., 2000). It was also anticipated that a statistical relationship between site productivity and the physical, chemical and microbiological properties of the sites would be found to explain the effects of the fertilisation and organic matter removal treatments on site productivity.

All of these hypotheses will also be considered in terms of the time that has elapsed since the application of the management practices at the sites, allowing the relative persistence of the effects on the characteristics of the sites to be determined, as well as any potential implications for the long term sustainability of forestry at the sites. The hypotheses will be investigated by measuring four parameters, which are summarised below.

1. **Physical/Chemical Environment**

   Determining the long term effects of the management practices on a number of physical and chemical parameters of the soil and litter layer is focus of the first part of this thesis. This is fundamental, as it provides a basis for later discussions on how and why the microbial community reacts to fertilisation and organic matter removal, based on alterations to the selection pressures, as determined by the physical and chemical parameters, on the soil and litter microbial community.

2. Microbial Community Biomass

The effects of fertilisation and organic matter removal on soil and litter microbial community biomass will be measured, and any relationships between microbial biomass and the environmental conditions will be determined.

3. Microbial Community Diversity Measurements

The effects of fertilisation and organic matter removal on soil and litter microbial community diversity will be determined based on measurements of functional diversity, and will also be considered in terms of the environmental conditions.

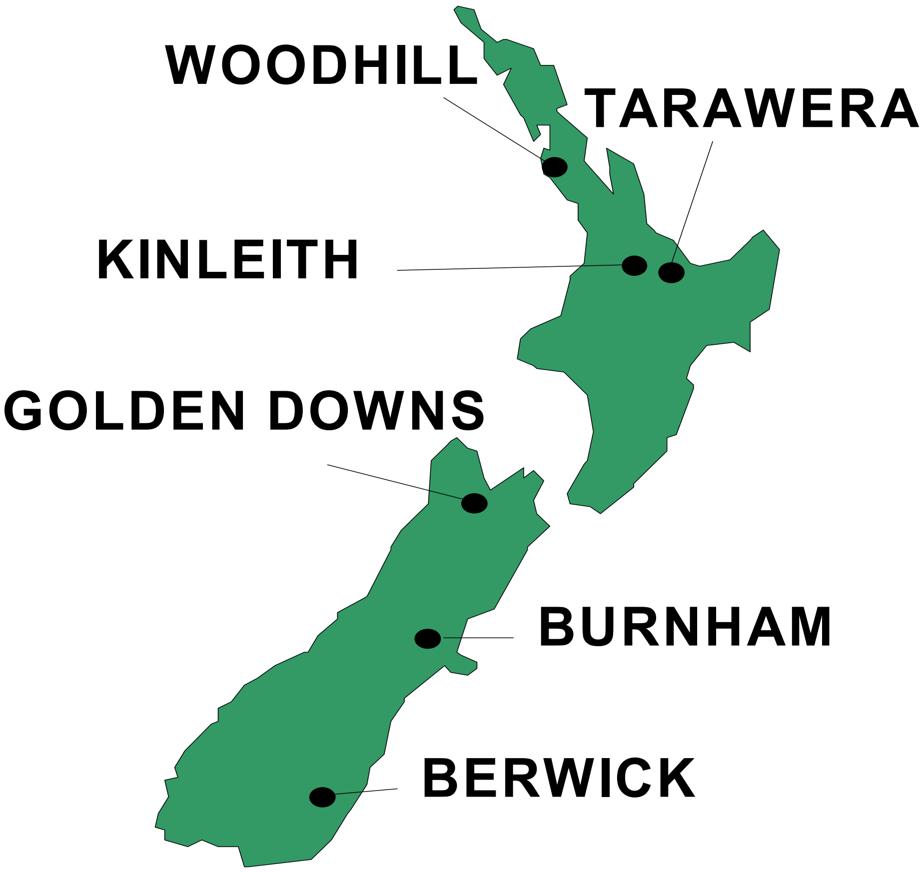
4. Forest Productivity Effects

The effects of fertilisation and organic matter removal on forest productivity parameters will be determined, and these will also be analysed to identify any correlations with parameters describing the physical and chemical conditions at the sites, as well as the microbial community.

1.7.3: Site Details and Descriptions

Six sites, situated in *Pinus radiata* D. Don. plantation forests, were used in this study. These sites were established by Forest Research New Zealand between 1986 and 1994 to comprise the intensive harvesting Long term Soil Productivity (LTSP) research program, and the locations of these sites are shown in Figure 1.1.

Figure 1.1: Relative Locations of LTSP Sites in New Zealand



All LTSP sites were in second rotation plantation forests, and were established after the harvest of the first rotation. As well as representing a climatic gradient, these sites also varied in soil type, development and other physical characteristics, which are presented in Table 1.1. Prior to the harvest of the first rotation, various soil parameters of the different sites were measured (Clinton, 2005), and these are given in Table 1.2.

Table 1.1: Initial Characteristics of the Long Term Soil Productivity Sites

	Woodhill	Tarawera	Berwick	Burnham	Kinleith	Golden Downs
Established	7/1986	8/1989	7/1990	7/1990	9/1992	7/1994
Soil Type	Pinaki Sand	Tarawera Gravel	Waitahuna and Heavy Silt Loam	Lismore Silt Loam	Taupo Sandy Loam	Spooner Hills
Latitude	36°43'S	38°13'S	46°00'S	43°37'S	38°14'S	41°36'S
Longitude	174°24'E	176°00'E	170°01'E	172°19'E	175°58'E	172°53'E
Elevation	30m	90m	200m	70m	400m	450m
Annual Rainfall	1330mm	1820mm	747mm	639mm	1420mm	1340mm
Mean Temp	14.3°C	14.0°C	10.3°C	11.5°C	13.2°C	10.4°C
Previous Crop	*Pinus radiata*	*Pinus radiata*	*Pinus radiata*	*Pinus radiata*	*Pinus radiata*	*Pinus nigra*

Table 1.2: Pre-Harvest Soil Characteristics at the Long Term Soil Productivity Sites

	Sampling Depth (mm)	Bulk Density (g cc^{-1})	pH	Carbon Content (%)	Nitrogen Content (%)	Carbon: Nitrogen ratio	Total Nitrogen (kg/ha)
Woodhill	0-100	1.41	5.60	0.40	0.02	21.39	214.32
		*	(0.03)	(0.03)	(0.00)	(1.00)	(7.35)
Tarawera	0-50	0.96	5.30	2.52	0.11	23.70	651.26
		(0.02)	(0.09)	(0.23)	(0.01)	(1.45)	(56.60)
Berwick	0-100	1.14	4.75	3.12	0.21	15.35	2361.87
		(0.03)	(0.02)	(0.10)	(0.01)	(0.39)	(137.34)
Burnham	0-100	1.17	4.86	3.35	0.20	16.60	1521.89
		(0.03)	(0.01)	(0.09v	(0.00)	(0.32)	(123.01)
Kinleith	0-100	0.60	NA	6.44	0.32	19.91	2039.39
		(0.02)		(0.24)	(0.01)	(0.65)	(125.54)
Golden Downs	0-300	NA	4.87	6.55	0.26	24.36	1704.28
			(0.10)	(2.25)	(0.08)	(0.50)	(445.54)

Values for the Standard Error of the Mean (SEM) are given in parentheses
NA indicates this parameter was not measured at this site
* Only one value was obtained for this parameter, so SEM was not calculable

The LTSP sites were installed with the objective of determining the long term effects of combinations of different levels of post harvest organic matter removal and fertilisation regimes on productivity across a range of forest sites. Consequently, all sites were comprised of replicated treatment plots that have undergone identical treatment combinations, allowing both intra- and inter-site comparisons to be made. Furthermore, a number of previous studies have reported results from these sites (Smith *et al*., 1994a, 1994b; Smith *et al*., 2000), allowing this study to add on to a pre-existing body of work regarding other short and long term effects of management at these sites.

1.7.4: Site Treatment Regimes

The first rotation stands at all sites were clearfelled using chainsaws, and heavy machinery was kept off areas where experimental plots were to be established to avoid causing soil compaction and disruption. The sites were then divided into plots, measuring either 900m^2 or 1600m^2 in area depending on site, with centralised interior 400m^2 areas marked out, in which the treatments were applied. Two organic matter removal treatments were common to all sites, and these were whole-tree harvesting (WT), where the entire tree and all associated above-ground organic matter was removed from this site, and stem-only harvesting (SO), where the organic harvesting residues (branches, needles, cones etc.) were left on the plots, and only the tree trunk was removed. A third treatment, whole-tree harvest plus forest floor removal (FF) was also applied at the Woodhill, Tarawera, Kinleith and Golden Downs sites. In these treatment plots, as well as removing the entire tree, the forest floor litter layer was also completely removed, leaving the soil surface exposed. One of these organic matter removal treatments was applied to two adjacent plots at the sites, using a split-plot randomised block design. Nitrogenous fertiliser was then applied by hand to one of each of the adjacent plots (FERT), and the other was left unfertilised (NO FERT). Phosphorous, boron, potassium and magnesium were also applied to fertilised plots, depending upon the nutritional requirements of the site. This made for a total of six different combinations of organic matter removal and fertilisation at the Woodhill, Tarawera, Kinleith and Golden Downs sites, and four at

Berwick and Burnham. These combinations (listed with abbreviations in Table 1.3) were replicated in four blocks at all sites with the exception of Woodhill, where three replicate blocks were installed.

Table 1.3: Long Term Soil Productivity Trial Treatments

	Fertilised	**Not Fertilised**
Stem Only Harvest	F SO	NF SO
Whole Tree Harvest	F WT	NF WT
Forest Floor Removal	F FF	NF FF

The presence or absence of weed control was also a treatment at several of the LTSP sites, but only the treatment plots that received weed control were used in this study, as it has been recommended that weed competition be eliminated when assessing long term site responses and productivity (Dyck *et al*., 1989). Weed control was carried out by manual weeding at site establishment, and applications of the herbicide Velpar (Hexazinone) were carried out at regular intervals until canopy closure. Roundup (Glyphosate) was also applied at Kinleith, but only in 1995.

CHAPTER TWO: SILVICULTURAL TREATMENT EFFECTS ON SOIL AND FH LITTER LAYER PHYSICAL AND CHEMICAL ENVIRONMENT

2.1: INTRODUCTION

Plantation forest ecosystems undergo removals of plant organic matter on a regular basis. The harvesting and removal of only merchantable stems (SO) at the end of a rotation is the most obvious example of this (Jorgensen *et al*., 1975), but other harvesting practices are also utilised in the forestry industry, which can increase the removal of plant organic matter. In some plantations whole tree harvesting (WT) is employed, by which the stem and all associated residues, such as bark, lateral branches, needles and pine cones, are removed from the site, rather than being left on the forest floor (Bååth, 1980; Bengtsson *et al*., 1998; Briggs *et al*., 2000). In other settings, the accumulated layer of needles, branches and other plant matter on the forest floor is removed from the site, in addition to the removal of harvest residues (FF), as part of the site preparation for the next rotation of trees (Ohtonen *et al*., 1992; Burgess and Wetzel, 2000; Chow *et al*., 2002).

Tree harvesting has been found to have a range of effects on the properties of the soil and litter layer, such as decreasing soil nutrient concentrations in some circumstances, decreasing soil solution pH and causing alterations to the variation in soil and litter temperature and moisture levels (Jorgensen *et al*, 1975; Bååth, 1980; Ballard, 2000; Bock and Van Rees, 2003). Harvesting has also been associated with increased nutrient losses via leaching in particular locations, though this is not generally the case (Johnson, 1994). Nutrient removal from WT harvesting treatments has been shown to be significantly greater than under SO harvesting regimes (Jorgensen *et al*, 1975; Bååth, 1980; Johnson, 1994; Richter *et al*., 2000), and as the FF harvesting treatment produces greater levels of organic matter removal, it is reasonable to assume this treatment results in the greatest level of nutrient loss.

What has not been as clearly documented is how the effects of harvesting may be moderated by the differing levels of organic matter removal associated with the SO, WT and FF harvesting practices outlined above. Variation in harvesting practices can influence physical and chemical characteristics in the forest floor litter layer and soil, such as average soil temperatures, which have been found to be significantly more variable at sites where the forest floor litter layer has been removed (Donnelly and Shane, 1986; Skinner *et al*., 1989), while daytime soil temperatures are greater at sites where the forest floor layer has previously been removed (Ohtonen *et al*., 1992; Ballard, 2000). It has also been proposed that soil moisture levels fluctuate over a wider range in response to increasing levels of organic matter removal (Bååth, 1980), and soil moisture levels have also been related to the fluctuations in soil temperature (Skinner *et al*., 1989).

Organic matter removal regimes have also been found to significantly decrease the populations of predatory soil animals when compared to sites with larger forest floor litter masses (Bengtsson *et al*., 1998), and have resulted in alterations to earthworm populations (Jordan *et al*., 1999; 2000). The inputs of coarse woody debris (CWD) associated with SO harvesting do not occur under WT and FF harvesting regimes, and this can have important implications for the litter and soil environment, as CWD removal has been found to decrease mean C:nutrient ratios, increasing nutrient availability in forests (Zimmerman *et al*., 1995), while CWD also serves as a site for nitrogen fixation (Harmon *et al*., 1986; Wei and Kimmins, 1998).

These findings indicate that the prevention of harvest residues from accumulating in the litter layer, or the entire removal of the litter layer immediately following harvesting, can have significant implications for the chemical and physical soil and litter environment during the life of the following rotation, but these effects have yet to be systematically examined across a range of sites.

The application of fertilisers containing nutrients such as nitrogen, phosphorus and boron to forest soils has become a common management practice worldwide. Nutrient availability is an important factor in maximising plantation growth rates, and as nutrient pools are diminished by the removal of plant material, fertilisation regimes are often used to replace the lost nutrients. Furthermore, nutrient limitations can also induce the development of plant disorders, further retarding growth rates (Arnebrant *et al*., 1990; Carlyle, 1995; Thomas *et al*., 1999). Mechanisms for the indirect addition of nutrients to forest soils have also been identified, such as deposition resulting from urban and industrial air pollution. This phenomenon has been reported to alleviate nitrogen limitation in some forested areas, as ambient annual nitrogen deposition has been found to range from 12 to 24 kg N ha^{-1} in parts of Scandinavia (Jonsson *et al*., 2000; Sjöberg *et al*., 2004). However, nitrogen deposition has been linked to decreased fungal diversity (Markkola *et al*., 1995; Brandrud and Timmermann, 1998), alterations to soil and litter carbon cycling (Allen and Schlesinger, 2004; Sjöberg *et al*., 2004) and also complicates the collection of baseline information regarding "natural" ecosystem processes (Hedin *et al*., 1995).

Forest fertilisation can result in ecosystem effects beyond adjustments to the availability of nutrients, potentially inducing alterations in a range of other physical and chemical soil and litter layer characteristics. Although the addition of urea can cause a short-term soil pH increase, the long term effect of urea and other nitrogenous fertiliser applications tends to be a decrease in soil pH (Ballard, 2000). This is supported by a review of research based in Swedish forests, which determined that mineral soil pH is significantly decreased by the addition of nitrogenous fertilisers, if nitrification is induced (Nohrstedt, 2001). The same effect has been reported in Australian eucalypt plantations, where the addition of nitrogenous fertiliser, in combination with phosphorous, resulted in increased nitrate levels and decreased soil pH values, up to four years after treatment (Smethurst *et al*., 2001). Increases in soil acidity resulting from nitrogen fertilisation have also been reported to be associated with long term increases in the leaching of nutrients and trace elements, based on trials in a *Pinus sylvestris* L. forest, where the addition of 1800kg of nitrogen per hectare over twenty years significantly decreased soil pH and increased the concentrations of aluminium, magnesium, nitrate and total nitrogen in soil solutions collected from the trial (Ring, 2004).

The application of fertilisers in forest ecosystems can also cause alterations to the accumulation, quality and rate of decomposition of plant organic matter in the forest floor litter layer. In three phosphorus deficient *Pinus elliottii* stands, established in 1966, 1971 and 1983, phosphorus application increased the forest floor litter layer mass and decreased the rate of litter decomposition, which was potentially the result of lower nitrogen:

phosphorus ratios in the litter (Wienand and Stock, 1995). Increased litter accumulation has also been reported in other research, where litter layer mass in a mixed forest was found to be significantly greater three years after fertilisation was ceased (Scroth *et al*., 2002).

The aim of the second chapter of this thesis is to determine the effects of fertiliser application and organic matter removal, described in section 1.6.4, on a range of physical and chemical parameters in the forest floor environment at the LTSP sites. This is crucial to the overall results of this study, as analysis of these effects on the physical and chemical properties, such as soil moisture and nutrient content, can identify the mechanisms responsible for any treatment effects on microbial community properties (Bååth, 1980, Ohtonen *et al*., 1992; Kennedy and Gewin, 1997). Additionally, the potential for fertilisation to mitigate the effects of organic matter removal was of interest, and interactions between the two treatments will be assessed. Consequently, the following hypotheses will be addressed:

1. Fertilisation increased litter layer mass, and the moisture content in the soil and litter layer.
2. Fertilisation increased the nitrogen content in the soil and litter layer, and decreased the C:N ratio in the soil and litter layer
3. Fertilisation decreased the soil pH
4. Increasing organic matter removal decreased litter layer mass, and the moisture content in the soil and litter layer.
5. Increasing organic matter removal decreased the nitrogen content in the soil and litter layer, and the C:N ratio in the soil and litter layer.
6. Fertilisation significantly mitigates the effects of organic matter removal.

The range of physical and chemical parameters examined in this chapter also included several not included in the above hypotheses, as these additional parameters were found to have use in discussions regarding the effects on the fertilisation and organic matter removal treatments on microbial community properties.

2.2: METHODS AND MATERIALS

2.2.1: Field Sites

The stem only (SO), whole-tree (WT) and whole-tree harvesting plus forest floor removal (FF) organic matter removal treatments, described previously in section 1.6.3, were applied after the first rotation was harvested at the six sites, and were not reinforced in any way following site establishment. The relative differences in the average mass and nitrogen removal from the plots as a result of these removals are shown below in Table 2.1 (Clinton, 2002). Thinning occurred at all sites, approximately 6 and 12 years after site establishment. To prevent thinning from confounding results, all treatment plots were thinned identically, and thinned stems, branches and needles were felled into the plots they grew in to prevent any cross over of plant material between adjacent treatment plots.

Table 2.1: Relative masses of organic matter and nitrogen removed from the LTSP sites

	FF TREATMENT		**WT TREATMENT**		**SO TREATMENT**	
	OM Removal (T ha^{-1})	Nitrogen Removal (kg ha^{-1})	OM Removal (T ha^{-1})	Nitrogen Removal (kg ha^{-1})	OM Removal (T ha^{-1})	Nitrogen Removal (kg ha^{-1})
WOODHILL	77.8	610.8	41.6	158.4	0	0
TARAWERA	54.1	507.8	30.2	157.9	0	0
BERWICK	NA	NA	44.2	156.2	0	0
BURNHAM	NA	NA	26.7	199.5	0	0
KINLEITH	70.5	605.8	45.4	170	0	0
GOLDEN DOWNS	148.8	540.8	122.9	378.1	0	0

NA indicates treatment was not applied at this site

Fertiliser application to the designated plots occurred on a regular basis after site establishment. Plots receiving fertiliser were labelled F, while unfertilised plots were designated NF. Urea was applied in quantities of 50 and 100 kg N ha^{-1} at regular intervals with the intention of preventing limitations to tree growth, and as the six sites varied in initial soil nutrient status, nitrogen application regimes differed substantially from site to site, as shown in Table 2.2. A number of other elements, such as phosphorus, calcium and potassium were also added to the fertilised plots, but the greatest numerical variation in nutrient application was in the masses of nitrogen added to the sites.

Table 2.2: Dates of application and total nitrogen additions to fertilised plots

	50 kg N ha^{-1}	**100 kg N ha^{-1}**	**Total kg N ha^{-1}**
WOODHILL	9/86, 12/86, 3/87, 6/87, 9/87, 12/87, 3/88, 6/88, 9/88, 12/88, 3/89, 6/89, 9/89, 12/89 3/90, 6/90, 10/90, 10/90, 5/91, 7/91, 10/91, 12/91, 3/92, 7/92, 10/92, 12/92, 3/93, 7/93, 10/93, 1/94, 4/94, 7/94, 10/94, 12/94, 3/95, 6/95, 9/95, 12/95, 3/96, 7/96, 9/96, 12/96	9/97, 9/98, 12/99 12/00, 12/01, 3/03*	2600 (2700)
TARAWERA	10/92, 10/92, 9/93, 1/94, 4/94, 7/94, 9/94, 12/94, 3/95, 7/95, 9/95, 12/95, 3/96, 6/96, 10/96	4/97, 2/98, 4/98, 9/98	1150
BERWICK	9/91, 3/92, 9/92, 3/93, 9/93, 3/94, 9/94, 6/95, 3/96, 9/96, 3/97	9/97, 3/98, 9/98, 3/99	950
BURNHAM	9/91, 3/92, 9/92, 3/93, 9/93, 3/94, 9/94, 3/95, 9/95† 3/96, 9/96, 3/97	9/97, 3/98, 9/98, 3/99	976
KINLEITH	8/93, 1/94, 4/94, 7/94, 9/94, 12/94, 3/95, 7/95, 9/95, 12/95, 3/96, 7/96, 10/96, 12/96, 4/97	10/97, 9/98	950
GOLDEN DOWNS	10/94, 1/95, 5/95, 8/95, 11/95, 3/96, 6/96, 9/96, 12/96, 2/97, 9/97, 12/97, 3/98, 5/98, 10/98, 3/99, 5/99		850

* This fertiliser application occurred between the summer and winter 2003 sampling rounds, so two totals are given for the Woodhill site.
† Only 26 kg N ha^{-1} was added in this fertilisation round

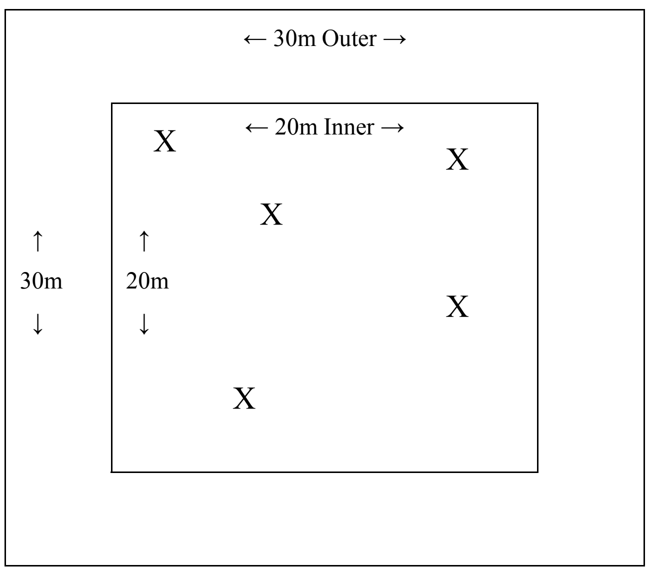
2.2.2: Sampling Regime

Site sampling rounds occurred at the times shown in Table 2.3. The sampling regime proceeded as described below, and was applied uniformly at all sites on all occasions. Five $0.1m^2$ quadrants (0.5m by 0.2m) were placed randomly within the $400m^2$ inner areas of the treatment plots, as shown in Figure 2.1 although there was a degree of bias to avoid sampling directly on top of felled logs or piles of branches resulting from thinning. This bias was employed as the thinned woody material did not meet the criteria for litter collection as described below, and accumulated needles and other plant litter on the surface of the thinned woody material, based on field observations, was not representative of the litter masses on the majority of the plot surface area.

Table 2.3: Sampling times at the six sites

	SUMMER 2002	WINTER 2002	SUMMER 2003	WINTER 2003
WOODHILL	January	August	January	August
TARAWERA	January	Not Sampled	February	Not Sampled
BERWICK	January	August	January	July
BURNHAM	February	Not Sampled	January	Not Sampled
KINLEITH	January	Not Sampled	February	Not Sampled
GOLDEN DOWNS	February	July	February	August

Figure 2.1: Plot litter and soil sampling regime



X indicates hypothetical sampling points

The material in the fresh plant litter layer (L horizon) within the bounds of the quadrant was identified by visual inspection, and was discarded. As the upper litter layers were removed, litter that had undergone visible degradation and colonisation by microorganisms was revealed (FH horizon), and this material was collected, down to the soil interface (Kavvadias *et al*., 2001) as shown in Figure 2.2. This material was designated FH litter. Another test applied to standardise litter collection was based on the degree of adhesion between needles and other types of litter. Fresh litter separated into individual needles and woody fragments when shaken manually, whilst the FH litter tended to adhere together, and could only be separated by "peeling" the needles apart. Woody debris and pine cones within the quadrant areas were also included, again based on the level of degradation, to avoid the inclusion of smaller fragments of recent pruning and thinning slash. This was based on visual indications, and also the physical pliability of the wood or pine cones, as easily crushed or bent specimens were included in the litter collections. The depth of the FH litter layer was also measured for each of the five litter collections in each plot, allowing the volume and bulk density of the FH litter to be calculated. Five samples were taken per plot to reduce the potential for lateral variability in the forest floor characteristics to skew results (Carter and Lowe, 1986).

Figure 2.2: Collection of FH litter

Soil samples were collected from the layer of mineral soil exposed in the quadrant area after the complete removal of the degraded litter layer. Soil sampling was biased to avoid large exposed stones and rock surfaces, although this was only regularly necessary in the Golden Downs plots. In most cases, the division between degraded litter and mineral soil was sharp, as shown in Figure 2.2, allowing a clear distinction to be made, but in some samples, the transition from litter to soil was continuous, and in these cases litter collection was considered complete when the organic matter was fragmented to the point where it was no longer recognisable. Mineral soil was collected using a soil corer 60mm in diameter, and cores were taken to a depth of 25mm. This relatively shallow depth of sampling was used as it was strongly suggested in the literature that microbial biomass is most concentrated in the topsoil (van Gestel *et al*., 1992; Dodds *et al*., 1996; Fritze *et al*., 2000), and practical considerations regarding the storage and transportation of the soil samples also prevented the collection of greater volumes of soil. Three samples were taken from the exposed soil from each quadrant, making a total of fifteen soil samples from each plot. These samples were pooled on site, resulting in one mixed soil sample for each plot. The soil and FH litter samples were transported to the laboratory as rapidly as possible, and were refrigerated during transit.

2.2.3: FH Litter Characterisation

In the laboratory, the fresh weights of the litter collections were recorded, and the five litter samples from each plot were pooled and mixed. Homogenisation of the litter material was performed either by using a concrete mixer or by hand, depending upon the mass of the samples to be combined. Sub-samples of the pooled litter were then taken, placed in pre-weighed containers, and dried using a fan-forced drying oven set at 65°C. The remaining fresh litter material was stored at 4°C for use in other analytical procedures, to be detailed in the following chapters. The drying litter samples were regularly shaken and turned to increase exposure to air currents, then removed from the oven after seven days, allowed to cool, then dried until a constant weight was obtained. If the litter samples were not dry after seven days, they were returned to the oven and reweighed after another seven days. The ash content of the litter was determined by placing known masses of dried litter sub-samples into pre-weighed crucibles, then heating the crucibles to 570^{o}C for 4 hours in a muffle furnace, incinerating the organic components of the litter (Chapman and Pratt, 1961). The bulk densities of the FH litter collected in each quadrant was then calculated by multiplying the volume the FH litter occupied by the oven dry ash free mass of the FH litter. The remaining dried litter material from the summer 2002 and summer 2003 sampling rounds were ground to 1mm, then analysed to determine nitrogen and carbon content, using a Leco Corporation CNS-2000 Elemental Analyzer. This analysis was not carried out on the litter material collected in either of the winter sampling rounds. The total mean masses of carbon and nitrogen in the FH litter layer in each of the plots was calculated by multiplying the mean FH litter mass, sampled from within the five 0.1m^2 quadrants in each plot, by the percentage of carbon or nitrogen in the FH litter, as determined by the Leco CNS-2000 Elemental Analyzer.

2.2.4: Mineral Soil Characterisation

The 15 fresh soil cores collected from each plot, if still intact, were broken up by hand, and thoroughly mixed until clumping of the soil was not evident. The fresh soil samples were then examined, and any recognisable plant matter was removed. The fresh soil was then passed through a 6mm sieve, and sub-divided. Two 20g sub-samples of the sieved soil from each plot were placed into pre-weighed containers, and heated in a drying oven set to 105^{o}C. Soil samples were allowed to dry for 4 days, cooled to room temperature in a desiccator, then reweighed until a constant weight was achieved to determine the moisture free weight of the soil samples. Additional soil samples from the summer 2002 sampling round were also dried using the same methodology, then ground to approximately 0.1mm, and analysed with a Leco Corporation CNS-2000 Elemental Analyzer to determine the nitrogen and carbon content of the soil. Soil solution pH was determined by the method described by Nicholson (1984). Moisture-free soil samples were mixed with distilled water in a 1:2.5 ratio, allowed to settle, then the pH of the solution was determined using a pH meter. The remaining sieved fresh soil was refrigerated for use in later procedures.

2.2.5: Statistical Analysis

The S-PLUS Version 6.0.3 statistical package (Lucent Technologies, Inc.) was used to perform statistical analysis of the data. Analysis of variance (ANOVA) was used to calculate significant effects and interactions of the treatments. Multiple comparison analyses (Tukey's) were then applied when necessary to the ANOVA results to determine the groupings of treatments and interactions based on statistical differences at $\alpha = 0.05$.

Data from the 2002 and 2003 summer collections were analysed separately for each site, as were the data for the winter collections performed at the Berwick, Golden Downs and Woodhill sites. The summer data for the six sites was then pooled by year, and statistical analysed. The 2002 and 2003 data was then combined, and the analyses were performed again.

The pooled data analyses were complicated by the lack of the FF organic matter removal treatment at the Berwick and Burnham sites, as this resulted in an unbalanced statistical design if all six sites were pooled and the effect of all three organic matter treatments were examined by ANOVA. Consequently, the differences between the SO and WT organic matter removal treatments were analysed using the pooled data from all sites, and a second analysis, using pooled data from the Golden Downs, Kinleith, Tarawera and Woodhill sites only, was performed to identify any significant differences between the FF, WT and SO organic matter removal treatments.

2.3: RESULTS

The physical and chemical parameters measured in the summer 2002, winter 2002, summer 2003 and winter 2003 sampling rounds are displayed in the following tables, presented individually by site and then pooled together. The numerical value of each parameter in each sampling round is given, with the standard error of the mean of that value (SEM) presented underneath in parentheses. All masses for parameters of the FH litter are given on an oven dry, ash free basis, and all masses for soil parameters are given on an oven dry basis. The terms used to identify the various treatments levels and parameters in the tables are as follows:

FERT	Fertilised plots
NO FERT	Unfertilised plots
FF	Whole-tree harvest plus forest floor removal plots
WT	Whole-tree harvest plots
SO	Stem-only harvest plots
FH Moisture	The mean proportion of moisture in fresh FH litter
FH Mass	The mean mass of the FH litter
FH Density	The mean density of the FH litter
FH % C	The mean percentage of carbon in the FH litter
FH % N	The mean percentage of nitrogen in the FH litter
FH Mass C	The mean mass of carbon contained in the FH litter
FH Mass N	The mean mass of nitrogen contained in the FH litter
FH C/N	The mean carbon: nitrogen ratio of the FH litter
Soil Moisture	The mean proportion of moisture in fresh soil samples
Soil pH	The mean pH of the soil samples
Soil % C	The mean percentage of carbon in the soil samples
Soil % N	The mean percentage of nitrogen in the soil samples
Soil C/N	The mean carbon: nitrogen ratio of the soil samples

In cases where the differences between the levels of a treatment effect, such as FF, WT and SO, have resulted in a statistically significant difference between the numerical values of a given parameter, a letter or letters have been used to designate the statistically distinct values or groups of values. If no letter is present, the values are indistinct at $\alpha = 0.05$ and there was no statistical difference between the treatment levels. Full summaries of the ANOVA calculations are presented in the Statistical Appendices (S. App.).

2.3.1: Woodhill Physical and Chemical Results

Effects of Fertilisation

The fertilised Woodhill plots contained significantly more moisture in the FH litter layer in summer 2002, but not in winter 2002 or either of the 2003 sampling rounds (Tables 2.4a and 2.4b). The response of the FH mass parameter was more consistent, as fertilised plots contained more FH litter than unfertilised plots in all sampling rounds, and the difference was statistically significant in all cases except summer 2002. The density of the FH litter varied considerably between sampling rounds, as the fertilised FH litter was significantly less dense in summer 2002, significantly more dense in winter 2002, and statistically indistinct from the FH litter collected from unfertilised plots in both 2003 sampling rounds. The carbon and nitrogen content of the FH litter from the fertilised plots was uniformly greater than in FH litter from unfertilised plots, and these differences were significant with the exception of carbon content in summer 2002, and the carbon: nitrogen ratio of the FH litter was statistically lower in fertilised plots in both summer sampling rounds. The mean masses of carbon and nitrogen present in the FH litter layer were statistically greater in the fertilised plots for both 2002 and 2003 sampling rounds. All of the measured soil parameters were statistically affected by the application of fertiliser at Woodhill in summer 2002. Soil moisture content was decreased, as was the soil pH. Fertilisation increased the mean percentages of carbon and nitrogen in the soil samples, and the carbon: nitrogen ratio was decreased.

Effects of Organic Matter Removal

The organic matter removal treatments did not statistically influence the moisture content, density or mass of the FH litter in any of the four sampling rounds, with the exception of FH litter layer mass in summer 2002, which was significantly less in the FF plots than either WT or SO plots. The mean moisture content of the FH litter was found to follow a uniform gradient in all sampling rounds, but the numerical difference was not significant in any case. The different levels of organic matter removal did not consistently or statistically affect the percentage of carbon in the FH litter,

Table 2.4a: Woodhill Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.57 **a**	9.20	142.40 **a**	35.65 **a**	1.26 **a**	3.31 **a**	0.12 **a**	28.18 **a**	0.07 **a**	4.74 **a**	1.07 **a**	0.04 **a**	28.00 **a**
	(0.02)	(0.83)	(10.68)	(1.75)	(0.06)	(0.38)	(0.01)	(0.35)	(0.00)	(0.06)	(0.19)	(0.01)	(1.80)
NO FERT	0.48 **b**	7.28	218.95 **b**	21.18 **b**	0.59 **b**	1.62 **b**	0.05 **b**	34.83 **b**	0.09 **b**	5.14 **b**	0.70 **b**	0.02 **b**	37.42 **b**
	(0.02)	(0.98)	(21.91)	(2.65)	(0.06)	(0.32)	(0.01)	(1.52)	(0.01)	(0.07)	(0.09)	(0.00)	(2.72)
FF	0.52	5.47 **a**	189.72	24.37	0.81	1.40 **a**	0.05 **a**	30.89	0.08	5.16 **a**	0.52 **a**	0.02	31.20
	(0.04)	(0.89)	(31.68)	(4.50)	(0.17)	(0.34)	(0.01)	(2.44)	(0.01)	(0.10)	(0.04)	(0.00)	(2.38)
WT	0.53	8.49 **b**	183.35	27.58	0.93	2.39 **b**	0.08 **b**	30.52	0.08	4.84 **b**	1.05 **b**	0.04	30.36
	(0.03)	(0.95)	(27.44)	(4.05)	(0.16)	(0.52)	(0.02)	(1.11)	(0.01)	(0.09)	(0.10)	(0.00)	(1.39)
SO	0.54	10.75 **b**	168.96	33.29	1.04	3.61 **c**	0.11 **c**	33.12	0.08	4.81 **b**	1.09 **b**	0.04	36.57
	(0.01)	(0.36)	(16.60)	(2.34)	(0.12)	(0.33)	(0.02)	(1.78)	(0.00)	(0.10)	(0.26)	(0.01)	(4.86)
SUMMER 2003													
FERT	0.66	3.91 **a**	122.27	46.65	1.49 **a**	1.82 **a**	0.06 **a**	31.47 **a**	0.24	NA	NA	NA	NA
	(0.01)	(0.21)	(4.40)	(0.89)	(0.03)	(0.10)	(0.00)	(1.20)	(0.03)				
NO FERT	0.63	1.16 **b**	125.62	44.96	1.09 **b**	0.52 **b**	0.01 **b**	44.16 **b**	0.23	NA	NA	NA	NA
	(0.02)	(0.22)	(8.16)	(1.40)	(0.07)	(0.10)	(0.00)	(5.43)	(0.03)				
FF	0.64	2.32	129.02	46.45	1.13 **a**	1.11	0.03	46.23	0.17 **a**	NA	NA	NA	NA
	(0.02)	(0.57)	(9.02)	(1.92)	(0.13)	(0.29)	(0.01)	(8.06)	(0.01)				
WT	0.65	2.59	113.88	44.19	1.38 **b**	1.17	0.04	32.38	0.20 **a**	NA	NA	NA	NA
	(0.02)	(0.69)	(5.62)	(0.98)	(0.07)	(0.33)	(0.01)	(1.11)	(0.01)				
SO	0.66	2.68	128.94	46.78	1.37 **b**	1.23	0.04	34.83	0.34 **b**	NA	NA	NA	NA
	(0.01)	(0.59)	(7.51)	(1.12)	(0.07)	(0.26)	(0.01)	(2.27)	(0.05)				

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Table 2.4b: Woodhill Physical and Chemical Parameters from Winter surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)		FH Density (kg/m^3)		Soil Moisture (kg/kg)	
WINTER 2002							
FERT	0.72	4.18	**a**	110.98	**a**	0.22	
	(0.01)	(0.33)		(2.02)		(0.02)	
NO FERT	0.71	1.48	**b**	88.82	**b**	0.24	
	(0.01)	(0.15)		(4.39)		(0.03)	
FF	0.70	2.46		95.33		0.16	**a**
	(0.01)	(0.60)		(7.85)		(0.01)	
WT	0.71	3.26		102.12		0.22	**a b**
	(0.01)	(0.71)		(4.89)		(0.01)	
SO	0.72	2.77		102.25		0.31	**b**
	(0.01)	(0.54)		(4.83)		(0.03)	
WINTER 2003							
FERT	0.70	4.39	**a**	140.49		0.18	
	(0.01)	(0.38)		(10.06)		(0.02)	
NO FERT	0.70	1.61	**b**	145.60		0.23	
	(0.01)	(0.18)		(7.43)		(0.03)	
FF	0.69	2.79		153.67		0.13	**a**
	(0.01)	(0.58)		(10.94)		(0.01)	
WT	0.70	3.41		142.03		0.21	**a b**
	(0.00)	(0.62)		(4.87)		(0.03)	
SO	0.71	2.81		133.43		0.21	**b**
	(0.01)	(0.77)		(13.32)		(0.02)	

Letters in bold indicate statistical groupings based on Tukey’s multi-comparison analysis test but the nitrogen content was determined to be lower in FH litter from the FF plots, although this was only significant in the summer 2003 sampling round.

The total masses of carbon and nitrogen present in the FH litter layer of the FF, WT and SO plots were all statistically distinct in summer 2002, but in the summer 2003 sampling round no significant differences were found. The moisture content of soil samples collected from SO plots was found to be statistically greater than that of soil from FF plots in all sampling rounds except summer 2002, and the moisture content of the soil from SO plots was also greater than the WT plots in summer 2003. The pH of the soil samples taken from FF plots was significantly greater than the pH of the WT and SO soil samples. The percentage of carbon and nitrogen in the FF plot soil samples were found to be lower than in either WT or SO plots, although the differences were only significant for the carbon content.

Significant Treatment Interactions

Several significant treatment interaction terms were found in the analysis of the Woodhill data. In the summer 2002 sampling round (refer S. App. 1.1.1), the mean soil moisture content in fertilised and unfertilised SO plots were statistically indistinct, but the moisture content of the soil in the fertilised FF and WT plots was less than that in the unfertilised FF and WT plots respectively. The percentage of carbon in the soil samples from the summer 2002 sampling round also varied with treatment combinations, as the soil carbon content in samples from fertilised SO plots were significantly greater than that in unfertilised SO plots, but there was no difference between soils from fertilised and unfertilised FF and WT plots. In the 2003 sampling round an interaction term was found in the analysis of the FH density data (S. App. 1.1.2). The density of the FH litter was significantly lower in fertilised FF plots than in WT plots, but in unfertilised plots the density of the FH litter was statistically greater in FF plots than in WT plots. The density of the FH litter was significantly less in fertilised FF plots than in unfertilised FF plots. An interaction term was also found in the statistical analysis of the winter 2002 FH moisture content data (S. App. 1.1.3), as the moisture content of the fertilised FF plots were significantly greater than the FH moisture content of the unfertilised FF plots, while the response of the fertilised and unfertilised WT and SO plots was the same.

Effects of Year and Season

The results at Woodhill differed in all common parameters between the summer 2002 summer 2003 sampling rounds (refer S. App. 1.1.5). In 2002 both the FH litter and soil contained significantly less moisture than in 2003. The mass of FH litter was statistically greater in 2002, and the litter was also denser. The FH litter contained greater percentages of carbon and nitrogen in 2003, but the total masses of carbon and nitrogen held in the FH litter layer were greater in 2002, and the carbon: nitrogen ratio of the FH litter was lower in 2002. The only statistical difference between the two winter sampling rounds at Woodhill was in the FH density parameter, which was significantly greater in 2003 (S. App. 1.1.6).

The four parameters measured in both summer and winter sampling rounds at Woodhill differed significantly between the seasons (S. App. 1.1.7), although the direction of the difference was not consistent for all parameters. The moisture content of the FH litter was lower in the summer sampling rounds, but the difference between summer and winter was much greater in 2002. The mass and density of the FH litter collected was greater in summer in 2002, but in 2003 the FH mass was greater in the winter sampling round, and the density of the FH litter was not affected by season. The moisture content of the soil samples was lower in summer in the 2002 sampling rounds, but no significant difference was found between summer and winter in 2003.

2.3.2: Tarawera Physical and Chemical Results

Effects of Fertilisation

The FH litter in the fertilised Tarawera plots contained statistically more moisture than the unfertilised plots at the time of the summer 2002 sampling round, but this trend was not repeated in summer 2003. The mass of FH litter present on the forest floor was significantly increased by the application of fertiliser in both years, and although the density of the FH litter was also greater in fertilised plots in both years the increase was not significant. The concentration of carbon in the FH litter was statistically greater in the fertilised plots in summer 2002 (Pr (F) = 0.01) but not in summer 2003 (Pr (F) = 0.83), but the concentration of nitrogen was significantly increased by fertilisation in both sampling rounds. The carbon: nitrogen ratio of the FH litter collected from the fertilised plots was also significantly lower than that of the FH litter from unfertilised plots. The total masses of carbon and nitrogen held in the FH litter layer were statistically greater in the fertilised plots for both 2002 and 2003 sampling rounds. The soil samples collected from fertilised plots differed considerably from soil taken from unfertilised plots. The pH of the fertilised soil was significantly lower, and the mean carbon and nitrogen content significantly greater. The carbon: nitrogen ratio of the soil from fertilised was also found to be statistically lower.

Effects of Organic Matter Removal

The different levels of the organic matter removal treatments applied at Tarawera did not produce significant differences in the moisture content and density of the FH litter layer, but the mass of litter present was found to be statistically greater in the SO plots than in the FF plots in both sampling rounds. The percentage of carbon in the FH litter in the FF plots was significantly lower than in the SO plots in 2002, though this parameter was not statistically affected in 2003. Similarly, in 2002 the percentage of nitrogen in the FH litter was determined to be statistically lower in the FF plots than either WT or SO plots, but no significant differences were found in 2003. The carbon: nitrogen ratio of the FH litter was not significantly by the organic matter removal treatments in either year. The organic matter treatments affected the total masses of carbon and nitrogen extant in the FH

Table 2.5: Tarawera Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.70 **a**	2.93 **a**	93.02	40.50 **a**	1.40 **a**	1.19 **a**	0.04 **a**	29.05 **a**	0.27	4.65 **a**	5.86 **a**	0.30 **a**	19.52 **a**
	(0.01)	(0.23)	(4.08)	(0.77)	(0.03)	(0.10)	(0.00)	(0.59)	(0.01)	(0.11)	(0.56)	(0.03)	(0.39)
NO FERT	0.67 **b**	1.70 **b**	85.14	35.09 **b**	1.05 **b**	0.62 **b**	0.02 **b**	33.53 **b**	0.28	5.16 **b**	4.39 **b**	0.19 **b**	23.97 **b**
	(0.01)	(0.23)	(5.03)	(1.86)	(0.05)	(0.10)	(0.00)	(0.64)	(0.01)	(0.09)	(0.46)	(0.02)	(1.00)
FF	0.67	1.70 **a**	86.20	33.80 **a**	1.08 **a**	0.61 **a**	0.02 **a**	31.58	0.23 **a**	5.13	3.22 **a**	0.15 **a**	22.49
	(0.02)	(0.26)	(6.74)	(2.10)	(0.08)	(0.12)	(0.00)	(0.69)	(0.01)	(0.15)	(0.23)	(0.02)	(1.84)
WT	0.69	2.43 **a b**	88.76	38.72 **a b**	1.28 **b**	0.96 **a b**	0.03 **a b**	30.91	0.30 **b**	4.81	5.59 **b**	0.26 **b**	21.48
	(0.01)	(0.36)	(3.18)	(1.69)	(0.08)	(0.16)	(0.01)	(1.43)	(0.01)	(0.12)	(0.62)	(0.03)	(0.72)
SO	0.70	2.81 **b**	92.28	40.86 **b**	1.31 **b**	1.16 **b**	0.04 **b**	31.38	0.30 **b**	4.78	6.55 **b**	0.31 **b**	21.28
	(0.01)	(0.31)	(6.50)	(1.11)	(0.05)	(0.14)	(0.00)	(1.02)	(0.01)	(0.14)	(0.47)	(0.03)	(0.67)
SUMMER 2003													
FERT	0.27	2.62 **a**	107.80	43.26	1.27 **a**	1.13 **a**	0.03 **a**	34.42 **a**	0.06	NA	NA	NA	NA
	(0.01)	(0.32)	(10.42)	(1.66)	(0.05)	(0.15)	(0.00)	(0.97)	(0.01)				
NO FERT	0.29	1.29 **b**	104.74	43.72	1.04 **b**	0.56 **b**	0.01 **b**	42.16 **b**	0.06	NA	NA	NA	NA
	(0.02)	(0.16)	(7.61)	(1.01)	(0.03)	(0.07)	(0.00)	(1.38)	(0.01)				
FF	0.28	1.39 **a**	119.12	41.64	1.07	0.57 **a**	0.02 **a**	39.44	0.03 **a**	NA	NA	NA	NA
	(0.03)	(0.22)	(16.59)	(1.48)	(0.05)	(0.08)	(0.00)	(2.18)	(0.00)				
WT	0.28	1.81 **a b**	99.18	44.82	1.22	0.81 **a b**	0.02 **a b**	37.58	0.07 **b**	NA	NA	NA	NA
	(0.01)	(0.23)	(6.85)	(1.52)	(0.07)	(0.11)	(0.00)	(1.92)	(0.01)				
SO	0.27	2.67 **b**	100.52	44.01	1.18	1.15 **b**	003 **b**	37.85	0.07 **b**	NA	NA	NA	NA
	(0.01)	(0.50)	(4.73)	(1.81)	(0.06)	(0.22)	(0.01)	(1.82)	(0.01)				

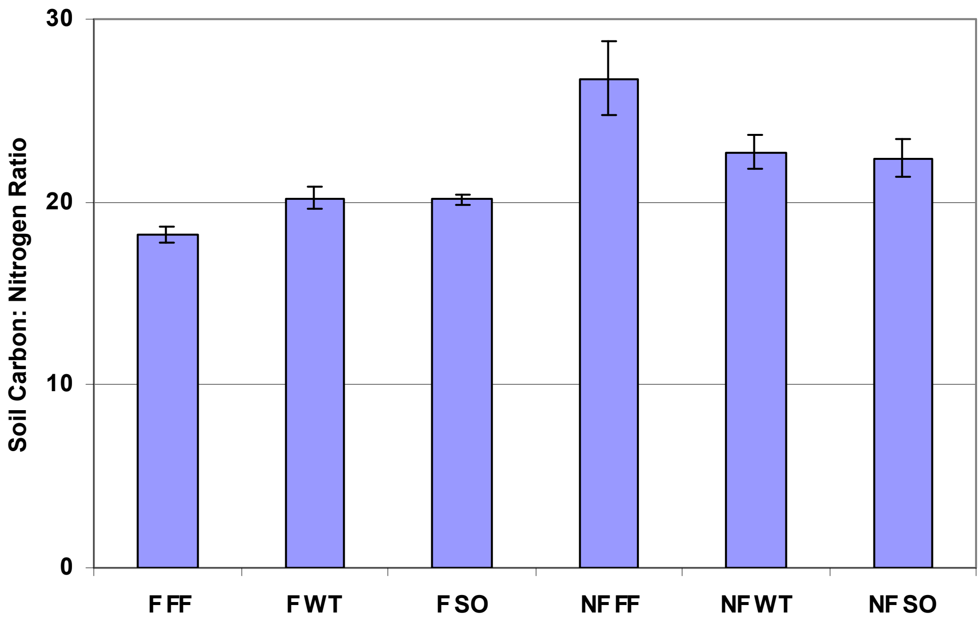
NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

litter layer, as significantly less of both elements were contained in the FF plots than the SO plots in either year. Soil samples collected in 2002 from FF plots were also found to contain significantly less carbon and nitrogen when compared with soil from WT and SO plots.

Significant Treatment Interactions

A significant treatment interaction was detected in the statistical results of the summer 2002 Tarawera data (S. App. 1.2.1), presented graphically in Figure 2.3. The mean carbon: nitrogen ratio of soil samples in the fertilised plots (F) was the same in the FF, WT and SO plots, but in the unfertilised plots (NF) the soil sample carbon: nitrogen ratio was significantly greater in the FF plots than the WT or SO plots. Furthermore, the soil carbon: nitrogen ratios in the fertilised WT and SO plots were statistically indistinct to the unfertilised WT and SO plots respectively, but the soil carbon: nitrogen ratio in the fertilised FF plots was lower than that in the unfertilised FF plots.

Figure 2.3: Effect of Treatments on Soil C: N ratios at Tarawera in 2002



Error bars indicate the standard error of the mean

Effects of Year

The moisture contents of both the FH litter and soil samples were significantly greater in 2002 (refer S. App. 1.2.3). The FH litter was denser in 2003, and also contained a significantly greater percentage of carbon. The mass of nitrogen contained in the forest floor FH litter was greater in 2002, and the carbon: nitrogen ratio of that litter was lower than in 2003.

2.3.3: Berwick Physical and Chemical Results

Effects of Fertilisation

Berwick plots receiving fertiliser were found to have greater masses of FH litter present on the forest floor, although this increase was found to be statistically significant for the summer 2003 and winter 2003 sampling rounds only. FH litters collected from fertilised plots in summer 2002 were found to contain significantly greater percentages of nitrogen than unfertilised plots, but this was not observed in 2003. The total amount of carbon present in the FH litter layer was increased by fertilisation, though this increase was not statistically significant in 2002. The total amount of nitrogen was also increased by fertiliser application, and this increase was found to be significant in both 2002 and 2003. The carbon: nitrogen ratio of FH litter collected from fertilised plots was significantly lower in summer 2002, but this was not found in the summer 2003 sampling round. Fertilisation was found to have no statistical effect on any of the parameters describing the condition of the soil.

Effects of Organic Matter Removal

The level of organic matter removal was significantly affected several physical and chemical parameters of the Berwick plots. The moisture contents of the FH litter in the WT plots was greater than the FH litter from the SO plots, though this difference was only significant in the two summer sampling rounds. The FH litter mass was greater in the SO plots, and this difference was statistically significant in all cases except for winter 2003. The density of the FH litter was statistically greater in the SO plots than in the WT plots for both of the 2002 sampling rounds, and this trend was supported by the summer 2003 density results. However, in winter 2003 the FH density was significantly greater in the WT plots, disagreeing with the previous results. The organic matter removal treatments had no significant effect on the percentage of carbon and nitrogen in the FH litter collected from the plots, but the total masses of carbon and nitrogen held in the FH layer was statistically greater in the SO plots than in the WT plots. With regard to the measurements of the parameters of the soil, no statistically significant differences were found between the effects of the WT and SO treatments.

Table 2.6a: Berwick Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.66	3.83	74.12	44.02	1.28 **a**	1.68	0.05 **a**	34.97 **a**	0.29	4.30	9.42	0.50	18.67
	(0.01)	(0.47)	(4.42)	(0.99)	(0.07)	(0.21)	(0.01)	(1.79)	(0.02)	(0.08)	(0.68)	(0.03)	(0.40)
NO FERT	0.68	2.92	66.17	45.23	0.85 **b**	1.34	0.02 **b**	53.59 **b**	0.30	4.37	9.32	0.46	20.33
	(0.01)	(0.49)	(7.05)	(1.19)	(0.03)	(0.21)	(0.00)	(2.68)	(0.02)	(0.10)	(0.62)	(0.02)	(0.74)
FF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WT	0.69 **a**	2.61 **a**	59.62 **a**	44.14	1.03	1.15 **a**	0.03 **a**	45.13	0.30	4.25	8.91	0.45	19.83
	(0.01)	(0.43)	(5.48)	(1.28)	(0.08)	(0.20)	(0.01)	(3.84)	(0.01)	(0.10)	(0.62)	(0.03)	(0.71)
SO	0.65 **b**	4.14 **b**	80.66 **b**	45.10	1.11	1.87 **b**	0.05 **b**	43.43	0.30	4.43	9.83	0.51	19.17
	(0.01)	(0.36)	(3.94)	(0.90)	(0.10)	(0.16)	(0.01)	(4.14)	(0.02)	(0.07)	(0.65)	(0.02)	(0.59)
SUMMER 2003													
FERT	0.61	4.79 **a**	137.84	48.52	0.97	2.29 **a**	0.05 **a**	51.13	0.25	NA	NA	NA	NA
	(0.02)	(0.55)	(13.01)	(1.05)	(0.05)	(0.23)	(0.01)	(3.25)	(0.01)				
NO FERT	0.62	2.60 **b**	110.66	47.64	1.08	1.23 **b**	0.03 **b**	45.99	0.23	NA	NA	NA	NA
	(0.02)	(0.35)	(9.94)	(0.82)	(0.06)	(0.16)	(0.00)	(3.99)	(0.01)				
FF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WT	0.65 **a**	2.70 **a**	117.57	48.83	1.03	1.31 **a**	0.03 **a**	49.90	0.25	NA	NA	NA	NA
	(0.01)	(0.44)	(12.38)	(0.94)	(0.07)	(0.21)	(0.01)	(4.57)	(0.01)				
SO	0.58 **b**	4.69 **b**	130.93	47.33	1.02	2.21 **b**	0.05 **b**	47.22	0.23	NA	NA	NA	NA
	(0.02)	(0.52)	(12.24)	(0.89)	(0.05)	(0.23)	(0.00)	(2.60)	(0.02)				

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Table 2.6b: Berwick Physical and Chemical Parameters from Winter surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)		FH Density (kg/m^3)		Soil Moisture (kg/kg)
WINTER 2002						
FERT	0.70	2.66		79.88		0.42
	(0.01)	(0.46)		(8.41)		(0.01)
NO FERT	0.70	1.65		61.11		0.40
	(0.01)	(0.42)		(9.65)		(0.01)
FF	NA	NA		NA		NA
WT	0.72	1.32	**a**	56.09	**a**	0.40
	(0.01)	(0.24)		(6.36)		(0.01)
SO	0.69	3.00	**b**	84.90	**b**	0.43
	(0.01)	(0.47)		(9.68)		(0.01)
WINTER 2003						
FERT	0.66	2.82	**a**	117.29		0.21
	(0.01)	(0.24)		(7.87)		(0.01)
NO FERT	0.67	1.79	**b**	119.71		0.24
	(0.01)	(0.20)		(12.12)		(0.01)
FF	NA	NA		NA		NA
WT	0.68	2.09		135.75	**a**	0.22
	(0.01)	(0.28)		(8.85)		(0.01)
SO	0.65	2.52		101.25	**b**	0.23
	(0.01)	(0.27)		(7.52)		(0.01)

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Significant Treatment Interactions

No significant interactions at $\alpha = 0.05$ were found between the fertilisation and organic matter removal treatments in any of the Berwick sampling rounds.

Effects of Year and Season

The moisture content of the FH litter and soil samples was significantly greater in summer 2002 than in summer 2003, and the density and percentage of carbon in the FH litter was statistically greater in summer 2003 (refer S. App. 1.3.5). Significant differences between the winter sampling rounds were also calculated. The moisture content of both the FH litter and soil samples were greater in winter 2002 than winter 2003, and the density of the collected FH litter was greater in winter 2003 (S. App 3.6).

The moisture content of the FH litter collected in the summer sampling rounds was significantly less than that of FH litter collected in winter, and the mass of FH litter was also greater in summer (S. App 3.7). The moisture content of the soils samples was greater in winter 2002 than in summer 2002, but no significant difference was found between summer and winter 2003.

2.3.4: Burnham Physical and Chemical Results

Effects of Fertilisation

The application of fertiliser at Burnham resulted in increased moisture levels of the FH litter, although this trend was statistically significant for the summer 2003 sampling round only. The amount of FH litter present was also greater in the fertilised plots, but the difference between fertilised and unfertilised plots was not significant at $\alpha = 0.05$. The percentage of nitrogen in the FH litter collected from fertilised plots was greater than in FH litter taken from unfertilised plots, but this increase in nitrogen content was only statistically significant in summer 2002. Additionally, the total mass of nitrogen present in the FH litter layer was also significantly greater in fertilised plots in the 2002 sampling round, and the carbon: nitrogen ratio of the FH litter was significantly lower in 2002 also. The mean soil pH of the fertilised plots was found to be statistically lower then that of unfertilised plots, but no other soil parameters were significantly affected by the application of fertiliser.

Effects of Organic Matter Removal

Many of the physical and chemical parameters at the Burnham site were significantly affected by the organic matter removal treatment applied to a given plot. The mean values for the moisture contents of the FH layer, the total mass of FH litter present, and the density of the FH litter were all statistically greater in the SO plots than in the WT plots in summer 2002. The level of organic matter removal was found to have the same affect in the summer 2003 sampling round, but the difference between SO and WT plots was only statistically significant in the case of the FH density parameter. Similarly, the percentage of carbon in the FH litter, and the total masses of carbon and nitrogen contained in the FH layer were found to be significantly greater in the SO plots than in the WT plots in 2002, and although the numerical values for these parameters in the SO plots in 2003 were greater than those for the WT plots, the differences were not statistically significant at $\alpha = 0.05$. The only soil parameter that was affected by the organic matter removal treatment was the soil moisture content, which was found to be significantly greater in the SO plots in the summer 2003 sampling round.

Table 2.7: Burnham Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.56	2.94	80.15	35.54	1.28 **a**	1.07	0.05 **a**	28.21 **a**	0.20	4.22 **a**	6.76	0.43	15.62
	(0.01)	(0.41)	(5.26)	(1.24)	(0.07)	(0.18)	(0.01)	(1.23)	(0.01)	(0.05)	(0.57)	(0.04)	(0.25)
NO FERT	0.53	2.18	79.83	34.41	0.97 **b**	0.78	0.02 **b**	35.92 **b**	0.20	4.61 **b**	5.66	0.35	16.29
	(0.02)	(0.29)	(3.29)	(1.53)	(0.03)	(0.13)	(0.00)	(1.88)	(0.01)	(0.06)	(0.38)	(0.02)	(0.31)
FF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WT	0.52 **a**	1.86 **a**	73.51 **a**	32.86 **a**	1.06	0.62 **a**	0.02 **a**	32.04	0.20	4.47	5.92	0.37	15.89
	(0.02)	(0.15)	(2.86)	(1.21)	(0.07)	(0.07)	(0.00)	(2.15)	(0.01)	(0.11)	(0.61)	(0.04)	(0.32)
SO	0.57 **b**	3.27 **b**	86.47 **b**	37.09 **b**	1.19	1.23 **b**	0.04 **b**	32.08	0.21	4.36	6.50	0.41	16.01
	(0.00)	(0.37)	(4.45)	(1.17)	(0.08)	(0.16)	(0.01)	(2.03)	(0.00)	(0.05)	(0.40)	(0.03)	(0.29)
SUMMER 2003													
FERT	0.26 **a**	1.84	68.44	47.56	1.20	0.87	0.02	43.57	0.10	NA	NA	NA	NA
	(0.02)	(0.61)	(11.95)	(1.11)	(0.11)	(0.29)	(0.01)	(5.36)	(0.01)				
NO FERT	0.18 **b**	0.63	45.90	44.74	1.10	0.28	0.01	41.25	0.11	NA	NA	NA	NA
	(0.01)	(0.12)	(5.48)	(0.91)	(0.05)	(0.05)	(0.00)	(1.54)	(0.01)				
FF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WT	0.20	0.67	43.05 **a**	45.75	1.12	0.31	0.01	44.16	0.09 **a**	NA	NA	NA	NA
	(0.02)	(0.15)	(6.39)	(1.28)	(0.10)	(0.07)	(0.00)	(5.11)	(0.01)				
SO	0.24	1.80	71.30 **b**	46.55	1.17	0.85	0.02	40.66	0.12 **b**	NA	NA	NA	NA
	(0.02)	(0.61)	(10.67)	(0.94)	(0.07)	(0.29)	(0.01)	(2.13)	(0.01)				

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Significant Treatment Interactions

Two statistical interactions terms between the fertilisation and organic matter removal treatments were detected at Burnham in the results of the summer 2002 sampling round (refer S. App 4.1). The density of the FH litter was statistically greater in fertilised SO plots than in fertilised WT plots, but FH litter collected from the unfertilised SO and WT plots did not differ in density. Also, the pH of soil samples collected in fertilised plots were statistically the same from WT or SO plots, but the pH of soil samples taken from unfertilised SO plots was significantly lower than from unfertilised WT plots.

Effects of Year

In 2002 the moisture content of the FH litter layer at Burnham was significantly greater than in 2003, and the moisture content of the soil samples was also statistically greater in 2002 (refer S. App 4.3). The mass of FH litter on the forest floor was greater in 2002, and the FH litter was also significantly denser in 2002. The percentage of carbon in the FH litter was greater in 2003 than in 2002, and the carbon: nitrogen ratio of the FH litter was also statistically greater in 2003. The mass of nitrogen contained in the FH litter layer was significantly greater in 2002.

2.3.5: Kinleith Physical and Chemical Results

Effects of Fertilisation

The mass of FH litter present in the fertilised plots was greater than that in the unfertilised plots, and this difference was significant in 2003. In 2002 the nitrogen content of the FH litter was significantly greater in the fertilised plots, and the carbon: nitrogen ratio was lower, but the 2003 sampling round did not support these results. The total mass of carbon and nitrogen contained in the FH litter on the fertilised plots was greater than on the unfertilised plots for both 2002 and 2003, and was statistically greater in all cases, with the exception of the mass of carbon in 2002. The application of fertiliser had two significant effects on the soil parameters, increasing the mean nitrogen content of the soil and decreasing the carbon: nitrogen ratio.

Effects of Organic Matter Removal

The effects of the organic matter removal treatments on the physical and chemical parameters were inconsistent. In the summer 2002 sampling, statistically less FH litter mass was found in the WT plots than in the SO plots, and the value for the FF plots was statistically indistinct to both. In 2003, the lowest mass of FH litter was in the FF plots and the highest in the SO plots, although none of the differences were significant. The density of the FH litter was significantly lower in the WT plots in 2002, but this was not supported by the 2003 results. The FH litter collected from the WT plots contained significantly more nitrogen than material from the FF plots in 2002, but this was not found in the 2003 sampling round. In 2002 the total mass of carbon in the FH litter was significantly less in the WT plots than in the SO plots, but this effect was not maintained in the 2003 sampling. The total mass of nitrogen in the FH litter was significantly less in the FF plots than in the SO plots for both sampling rounds, but the value for the WT plots varied with year, as in 2002 the WT plots were statistically different from the SO plots, while in 2003 the WT plots were distinct from the FF plots. The different levels of the organic matter removal treatment produced statistically significant results on all of the soil parameters. The moisture content of the

Table 2.8: Kinleith Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.72	1.69	92.63	36.25	1.32 **a**	0.64	0.02 **a**	27.63 **a**	0.50	4.78	10.09	0.54 **a**	18.74 **a**
	(0.01)	(0.26)	(6.89)	(1.34)	(0.04)	(0.13)	(0.00)	(1.17)	(0.02)	(0.07)	(0.75)	(0.04)	(0.41)
NO FERT	0.70	1.37	100.23	38.63	1.07 **b**	0.54	0.01 **b**	38.12 **b**	0.46	4.71	9.54	0.45 **b**	21.35 **b**
	(0.02)	(0.22)	(7.63)	(0.95)	(0.06)	(0.09)	(0.00)	(3.01)	(0.02)	(0.07)	(0.76)	(0.03)	(0.43)
FF	0.69	1.31 **a b**	106.18 **a**	35.26	1.05 **a**	0.46 **a b**	0.01 **a**	36.59	0.43 **a**	4.88 **a**	7.01 **a**	0.38 **a**	18.77 **a**
	(0.02)	(0.14)	(6.17)	(0.99)	(0.09)	(0.05)	(0.00)	(4.75)	(0.01)	(0.07)	(0.31)	(0.02)	(0.37)
WT	0.73	1.08 **a**	76.29 **b**	37.46	1.32 **b**	0.40 **a**	0.01 **a**	28.80	0.49 **a b**	4.79 **a b**	11.03 **b**	0.55 **b**	20.73 **b**
	(0.01)	(0.09)	(7.99)	(1.10)	(0.05)	(0.03)	(0.00)	(1.44)	(0.02)	(0.07)	(0.69)	(0.05)	(0.75)
SO	0.70	2.20 **b**	106.81 **a**	39.60	1.21 **a b**	0.91 **b**	0.03 **b**	33.23	0.51 **b**	4.56 **b**	11.39 **b**	0.55 **b**	20.63 **b**
	(0.01)	(0.38)	(8.07)	(1.79)	(0.05)	(0.19)	(0.00)	(2.32)	(0.02)	(0.08)	(0.71)	(0.03)	(0.65)
SUMMER 2003													
FERT	0.50	2.44 **a**	211.33	47.57	1.44	1.16 **a**	0.03 **a**	33.53	0.34	NA	NA	NA	NA
	(0.03)	(0.20)	(17.62)	(0.95)	(0.04)	(0.10)	(0.00)	(1.48)	(0.02)				
NO FERT	0.45	1.74 **b**	210.23	48.30	1.44	0.84 **b**	0.02 **b**	34.09	0.31	NA	NA	NA	NA
	(0.02)	(0.18)	(16.08)	(0.34)	(0.05)	(0.09)	(0.00)	(1.33)	(0.02)				
FF	0.44	1.68	224.06	48.11	1.47	0.81	0.02 **a**	33.10	0.30	NA	NA	NA	NA
	(0.03)	(0.15)	(21.11)	(0.81)	(0.04)	(0.08)	(0.00)	(1.29)	(0.02)				
WT	0.47	2.18	216.09	47.73	1.44	1.05	0.03 **b**	33.77	0.31	NA	NA	NA	NA
	(0.02)	(0.30)	(18.75)	(0.90)	(0.06)	(0.16)	(0.00)	(1.98)	(0.02)				
SO	0.52	2.41	192.19	47.95	1.41	1.15	0.03 **b**	34.56	0.37	NA	NA	NA	NA
	(0.03)	(0.25)	(20.36)	(0.93)	(0.05)	(0.11)	(0.00)	(1.79)	(0.02)				

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

soil was greatest in SO treatment plots and lowest in the FF plots, although this was only significant in 2002. Soil pH values were highest in the FF plots and lowest in the SO plots, and the percentage of carbon and nitrogen in the soil were statistically lower in the FF plots than in either the WT or SO plots. The carbon: nitrogen ratio of the soil was lowest in the FF plots, and the WT and SO plots were statistically indistinct.

Significant Treatment Interactions

No significant interactions at $\alpha = 0.05$ were found between the fertilisation and organic matter removal treatments in any of the Kinleith sampling rounds.

Effects of Year

The moisture content of both the FH litter layer and the soil samples was greater in 2002 than in 2003 (refer S. App. 1.5.3). The mass and density of the FH litter was statistically greater in 2003, and the carbon and nitrogen content of the FH litter was also calculated to be significantly greater in 2003 than in 2002, although the carbon: nitrogen ratio of the FH litter did not differ significantly between the two sampling rounds. The total masses of carbon and nitrogen present on the forest floor in the FH litter layer were greater in 2003.

2.3.6: Golden Downs Physical and Chemical Results

Effects of Fertilisation

The response of the measured parameters to fertilisation at Golden Downs was inconsistent. FH litter in the fertilised plots had significantly greater moisture contents in the summer 2002 sampling round, but this was not found in any other samplings. Similarly, the density of the FH litter was significantly greater in fertilised plots in winter 2003, but this was not observed statistically at any other time. In the summer 2002 sampling round it was found that the percentage of nitrogen in the FH litter was increased by fertilisation, and the carbon: nitrogen ratio of the FH litter was decreased, but these results were not supported by the 2003 sampling round. The only soil parameter statistically affected by fertilisation was the soil carbon: nitrogen ratio, which was significantly lower in the fertilised plots.

Effects of Organic Matter Removal

Of the three levels of organic matter removal applied at Golden Downs, the greatest differences were found between the SO and FF treatments, and in several cases the plots that had received the FF treatment were statistically distinct from both the WT and SO treatments. The moisture content of the FH litter was highest in the SO and WT plots, although this was only observed in the summer sampling rounds. For all sampling rounds, the mass of FH litter was greatest in the SO plots and least in the FF plots, and the mass of FH litter in the WT plots was statistically indistinct from either the FF plots or both SO and FF plots, depending on the sampling round. The density of the FH litter was statistically lower in the FF plots, although this was only statistically proven for the summer and winter 2002 sampling rounds. In summer 2002 the FH litter from the FF plots contained less carbon, more nitrogen and had the lowest carbon: nitrogen ratio than FH litter from either WT or SO plots, although this was not statistically supported by the 2003 sampling round. The total masses of carbon and nitrogen contained in the FH litter were significantly lower in the FF plots than the SO plots for both summer sampling rounds, and the mass of nitrogen in the FF plots was also statistically less than that in the WT plots in summer

Table 2.9a: Golden Downs Physical and Chemical Parameters from Summer surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.47 **a**	2.40	62.63	48.95	1.15 **a**	1.23	0.02	44.17 **a**	0.20	5.29	13.68	0.53	25.21 **a**
	(0.02)	(0.54)	(8.65)	(1.33)	(0.06)	(0.28)	(0.01)	(3.05)	(0.01)	(0.06)	(1.18)	(0.04)	(0.76)
NO FERT	0.41 **b**	1.80	62.75	49.63	0.92 **b**	0.92	0.02	55.43 **b**	0.22	5.34	14.22	0.48	28.51 **b**
	(0.02)	(0.47)	(8.72)	(1.37)	(0.04)	(0.25)	(0.00)	(3.21)	(0.02)	(0.05)	(1.92)	(0.05)	(0.89)
FF	0.36 **a**	0.52 **a**	36.45 **a**	45.87 **a**	1.22 **a**	0.23 **a**	0.01 **a**	38.88 **a**	0.19	5.38	10.11	0.41	24.17 **a**
	(0.02)	(0.11)	(5.15)	(1.59)	(0.08)	(0.04)	(0.00)	(2.96)	(0.01)	(0.07)	(1.07)	(0.03)	(0.87)
WT	0.48 **b**	2.24 **b**	71.06 **b**	49.86 **a b**	0.96 **b**	1.14 **a b**	0.02 **b**	53.57 **b**	0.22	5.33	15.02	0.53	27.98 **b**
	(0.01)	(0.51)	(9.77)	(1.68)	(0.06)	(0.27)	(0.01)	(4.33)	(0.01)	(0.06)	(1.72)	(0.05)	(1.01)
SO	0.49 **b**	3.54 **b**	80.56 **b**	52.14 **b**	0.93 **b**	1.86 **b**	0.03 **b**	56.96 **b**	0.23	5.23	16.70	0.58	28.42 **b**
	(0.02)	(0.57)	(9.10)	(0.60)	(0.04)	(0.31)	(0.01)	(2.31)	(0.03)	(0.06)	(2.10)	(0.06)	(0.98)
SUMMER 2003													
FERT	0.15	1.89	137.27	50.12	1.07	0.94	0.02	49.73	0.09	NA	NA	NA	NA
	(0.01)	(0.37)	(12.85)	(0.51)	(0.07)	(0.18)	(0.01)	(3.54)	(0.01)				
NO FERT	0.15	1.47	130.57	49.71	1.16	0.73	0.02	43.94	0.08	NA	NA	NA	NA
	(0.01)	(0.32)	(7.73)	(0.95)	(0.05)	(0.16)	(0.00)	(2.23)	(0.01)				
FF	0.12 **a**	0.67 **a**	110.39	50.91	1.16	0.34 **a**	0.01 **a**	45.43	0.07 **a**	NA	NA	NA	NA
	(0.01)	(0.09)	(9.69)	(0.72)	(0.08)	(0.04)	(0.00)	(3.42)	(0.01)				
WT	0.15 **a b**	1.74 **a b**	154.69	49.24	1.09	0.85 **a b**	0.02 **a b**	47.15	0.08 **a**	NA	NA	NA	NA
	(0.01)	(0.33)	(14.91)	(1.20)	(0.08)	(0.16)	(0.00)	(4.15)	(0.00)				
SO	0.17 **b**	2.64 **b**	136.68	49.59	1.08	1.15 **b**	0.03 **b**	47.91	0.12 **b**	NA	NA	NA	NA
	(0.01)	(0.43)	(8.35)	(0.68)	(0.08)	(0.11)	(0.01)	(3.63)	(0.01)				

NA indicates treatment was not applied at this site, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Table 2.9b: Golden Downs Physical and Chemical Parameters from Winter surveys

	FH Moisture (kg/kg)	FH Mass (kg/m^2)		FH Density (kg/m^3)		Soil Moisture (kg/kg)	
WINTER 2002							
FERT	0.71	1.05		23.97		0.35	
	(0.01)	(0.30)		(4.52)		(0.02)	
NO FERT	0.70	1.02		24.81		0.37	
	(0.01)	(0.23)		(4.29)		(0.04)	
FF	0.71	0.23	**a**	9.27	**a**	0.30	**a**
	(0.02)	(0.05)		(1.37)		(0.02)	
WT	0.69	1.26	**b**	33.59	**b**	0.36	**a b**
	(0.01)	(0.29)		(5.09)		(0.03)	
SO	0.71	1.61	**b**	30.31	**b**	0.44	**b**
	(0.01)	(0.31)		(4.01)		(0.04)	
WINTER 2003							
FERT	0.69	1.87		154.96	**a**	0.30	
	(0.00)	(0.28)		(8.91)		(0.02)	
NO FERT	0.69	1.44		131.91	**b**	0.34	
	(0.01)	(0.20)		(9.09)		(0.04)	
FF	0.70	0.94	**a**	130.18		0.25	**a**
	(0.01)	(0.10)		(9.48)		(0.01)	
WT	0.69	1.76	**a b**	152.94		0.30	**a b**
	(0.01)	(0.19)		(14.48)		(0.03)	
SO	0.68	2.26	**b**	147.18		0.41	**b**
	(0.01)	(0.34)		(8.92)		(0.04)	

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

2002. Soil moisture content in the SO plots was statistically greater than in the FF plots for all sampling rounds except for summer 2002, but in this case the trend was still observed. The soil carbon: nitrogen ratio was statistically lowest in the FF plots at the time of the summer 2002 sampling.

Significant Treatment Interactions

A single statistical interaction between the fertilisation and organic matter removal treatments was detected in the summer 2003 sampling round (refer S. App. 1.6.2). The percentage of carbon in the FH litter was statistically the same in the FF and SO plots with or without fertilisation, but the carbon content of FH litter from the fertilised WT plots was significantly greater than that of the unfertilised WT plot FH litter.

Effects of Year and Season

At Golden Downs three of the measured parameters of the summer sampling rounds differed significantly from 2002 to 2003. The moisture content of the FH litter and soil samples was greater in 2002, and the density of the FH litter was greater in 2003 (refer S. App 6.5). Of the parameters measured in the winter sampling rounds, the mass of FH litter was found to be greater in 2003, and the FH litter was also found to be denser in winter 2003 than in winter 2002 (S. App. 1.6.6).

Seasonal differences in the measured parameters were calculated for 2002 and 2003 (S. App 1.6.7). The moisture content of the FH litter and soil was greater in winter for both years. The mass and density of the FH litter layer on the forest floor was greater in summer than in winter in 2002, but in 2003 these parameters did not differ significantly between summer and winter.

2.3.7: Effects of Fertilisation on Parameters at all Sites

When statistically analysed across all sites, using only the summer data sets, the addition of fertiliser resulted in a significant increase in the mean FH litter layer moisture content in summer 2002, but not in 2003. When the data for both sets was combined, the moisture content was significantly increased by fertilisation. The mass of FH litter present was significantly increased by fertilisation in both 2002 and 2003, and when the data from both years were combined. The response of FH density to fertilisation across all sites was inconsistent, and no overall trend was observed. The percentage of carbon and nitrogen in the FH litter from fertilised plots was statistically greater than that in FH litter from unfertilised plots in all cases with the exception of the carbon content in 2003, but the trend was still followed. FH litter from fertilised plots had a significantly lower carbon: nitrogen ratio in the 2002 and in the combined data sets, but the difference in the 2003 data set was not significant. The total masses of carbon and nitrogen in the FH litter layer were statistically greater in the fertilised plots in all cases. Soil moisture was unaffected by fertilisation in all data sets. Soil pH was significantly decreased by fertiliser addition in the summer 2002 sampling round, and the soil nitrogen content was significantly increased. The carbon: nitrogen ratio of the soil samples was statistically lower in the fertilised plots.

Significant Site: Fertilisation Interactions

All of the physical and chemical parameters were found to vary significantly from site to site in all combinations of the summer sampling rounds, and for many parameters a statistically significant site: fertilisation interaction terms were also calculated (refer S. App. 1.7.1 – 1.7.3). The responses of the nitrogen content and total masses of carbon and nitrogen in the FH litter layer to fertilisation varied statistically across the six different sites in the summer 2002, summer 2003 and the combined years data set. Soil pH and the soil carbon: nitrogen ratio were also affected differently by fertilisation at the different sites in the summer 2002 sampling round, and the effect of fertilisation on the mass of FH litter collected varied with site in the combined 2002 and 2003 data set, but did not vary significantly in either year individually.

Table 2.10: Mean Effect of Fertilisation on Physical and Chemical Parameters from summer surveys at all sites combined

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FERT	0.62 **a**	3.62 **a**	90.08	40.42 **a**	1.28 **a**	1.45 **a**	0.05 **a**	32.28 **a**	0.27	4.71 **a**	8.11	0.40 **a**	21.11 **a**
	(0.01)	(0.36)	(4.30)	(0.83)	(0.02)	(0.14)	(0.00)	(1.08)	(0.02)	(0.06)	(0.73)	(0.03)	(0.78)
NO FERT	0.58 **b**	2.70 **b**	100.26	37.84 **b**	0.92 **b**	0.93 **b**	0.02 **b**	41.88 **b**	0.27	4.93 **b**	7.60	0.33 **b**	24.85 **b**
	(0.02)	(0.32)	(7.77)	(1.32)	(0.03)	(0.09)	(0.00)	(1.53)	(0.02)	(0.05)	(0.71)	(0.03)	(0.96)
SUMMER 2003													
FERT	0.39	2.81 **a**	134.88	47.21	1.25 **a**	1.32 **a**	0.04 **a**	40.21	0.18	NA	NA	NA	NA
	(0.03)	(0.20)	(7.71)	(0.54)	(0.03)	(0.09)	(0.00)	(1.52)	(0.02)				
NO FERT	0.37	1.48 **b**	126.72	46.63	1.16 **b**	0.69 **b**	0.02 **b**	41.60	0.17	NA	NA	NA	NA
	(0.03)	(0.12)	(7.54)	(0.48)	(0.03)	(0.06)	(0.00)	(1.24)	(0.01)				
COMBINED													
FERT	0.51 **a**	3.22 **a**	112.48	43.82 **a**	1.27 **a**	1.39 **a**	0.04 **a**	36.25 **a**	0.22	NA	NA	NA	NA
	(0.01)	(0.21)	(4.86)	(0.58)	(0.02)	(0.08)	(0.00)	(1.27)	(0.01)				
NO FERT	0.48 **b**	2.09 **b**	113.49	42.23 **b**	1.04 **b**	0.81 **b**	0.02 **b**	41.74 **b**	0.22	NA	NA	NA	NA
	(0.01)	(0.81)	(5.55)	(0.81)	(0.02)	(0.06)	(0.00)	(0.99)	(0.01)				

NA indicates treatment was not applied, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

2.3.8: Effects of the Whole Tree Removal and Stem Only Removal Treatments at all Sites

The mean mass of FH litter from all six sites was significantly greater in SO plots than in WT plots for all three data sets. The FH litter layer was denser in SO plots, but this difference was only significant in the pooled summer 2002 data set. The mean percentage of carbon was statistically greater in FH litter collected from SO plots in summer 2002 and in the combined summer 2002 and 2003 data, but the difference between WT and SO plots was not significant in the 2003 data alone. No statistical treatment effects on the nitrogen content and carbon: nitrogen ratio of the FH litter were found. The mean masses of carbon and nitrogen contained in the FH litter layer were significantly greater in the SO treatment plots in all cases. The moisture content of soil samples taken from SO plots was also statistically greater in the summer 2003 sampling round and in the combined years data, but not in the summer 2002 data. No other significant treatment effects were found in the soil parameters measured in the summer 2002 sampling round.

Significant Site: Organic Matter Removal Interactions

The physical and chemical parameters of the WT and SO treatment plots varied significantly from site to site, and statistically significant site: organic matter removal interactions were also calculated for the FH and soil moisture content parameters (refer S. App. 1.8.1 – 1.8.3). In the summer 2002, summer 2003 and combined years data sets the sites varied in the response of the FH litter layer moisture content to the WT and SO treatments. The response of the soil moisture content parameter to the WT and SO treatments was also found to vary with site, in the case of the summer 2003 and combined years data sets.

Table 2.11: Mean Effect of Organic Matter Removal on Physical and Chemical Parameters from summer surveys at all sites combined

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
WT	0.61	2.89 **a**	88.13 **a**	38.91 **a**	1.10	1.06 **a**	0.03 **a**	37.10	0.27	4.74	8.22	0.38	22.38
	(0.02)	(0.38)	(7.09)	(1.28)	(0.04)	(0.13)	(0.00)	(1.79)	(0.02)	(0.06)	(0.73)	(0.03)	(0.78)
SO	0.61	4.18 **b**	99.74 **b**	41.70 **b**	1.14	1.69 **b**	0.05 **b**	38.59	0.28	4.69	9.01	0.42	23.12
	(0.01)	(0.42)	(5.38)	(1.03)	(0.04)	(0.15)	(0.00)	(1.72)	(0.02)	(0.06)	(0.80)	(0.03)	(1.17)
SUMMER 2003													
WT	0.39	1.92 **a**	124.52	46.87	1.21	0.91 **a**	0.02 **a**	41.19	0.16 **a**	NA	NA	NA	NA
	(0.03)	(0.18)	(9.40)	(0.56)	(0.04)	(0.09)	(0.00)	(1.77)	(0.01)				
SO	0.39	2.82 **b**	126.66	47.05	1.20	1.32 **b**	0.03 **b**	40.75	0.20 **b**	NA	NA	NA	NA
	(0.03)	(0.24)	(7.42)	(0.52)	(0.03)	(0.11)	(0.00)	(1.29)	(0.02)				
COMBINED													
WT	0.50	2.40 **a**	106.33	42.89 **a**	1.15	0.98 **a**	0.03 **a**	39.15	0.22 **a**	NA	NA	NA	NA
	(0.02)	(0.21)	(6.19)	(0.81)	(0.03)	(0.08)	(0.00)	(1.27)	(0.01)				
SO	0.50	3.50 **b**	113.20	44.37 **b**	1.17	1.51 **b**	0.04 **b**	39.67	0.24 **b**	NA	NA	NA	NA
	(0.02)	(0.25)	(4.79)	(0.64)	(0.02)	(0.10)	(0.00)	(1.08)	(0.01)				

NA indicates treatment was not applied, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

2.3.9: Effects of the Organic Matter Removal Treatments at the Woodhill, Tarawera, Kinleith and Golden Sites

The mean moisture content of the FH litter was significantly lower in the FF treatment plots than in the WT and SO plots in the summer 2002 sampling round, and in the combined data set from both years the FH litter in the FF plots was also statistically lower than in the SO plots, but not the WT plots. The response of the mass of FH litter present on the forest floor to the organic matter removal treatments was consistent in the three data sets. The FH mass was statistically lower in the FF treatment plots than in the WT treatment plots, which in turn contained significantly less FH litter than the SO plots. The density of the FH litter was not affected by the organic matter removal treatments. In 2002 the percentage of carbon in FH litter from the FF plots was statistically lower than that in the WT plots, which was lower than the SO plots, and the carbon: nitrogen ratio of the FH litter was significantly less in the FF plots than in the SO plots. These results were not observed in 2003, but in the combined 2002 and 2003 data, the carbon content of the FH litter from FF plots was significantly lower than in SO plots, and the nitrogen content was lower in the FH litter from FF plots than the WT and SO plots. The masses of carbon and nitrogen present in the FH litter layer of the four sites was significantly lower in the FF treatment plots, and in the 2002 and combined years data sets the carbon and nitrogen masses were statistically lower in the WT plots than in the SO plots as well. The mean soil moisture content was significantly greater in the SO plots and lower in the FF plots, and the statistical separation of the WT plots from FF and SO varied with the data sets. The three levels of organic matter removal produced significant differences in all of the soil parameters measured in 2002. The pH of the soil samples was greater in the FF plots than in the WT and SO plots, and the soil carbon and nitrogen content were significantly lower in FF plots. The soil carbon: nitrogen ratio was significantly lower in the FF soil samples than in the SO soil samples.

Significant Site: Organic Matter Removal Interactions

The measured parameters of the organic matter removal treatment plots were found to vary significantly between the four sites, and significant site:

Table 2.12: Mean Effect of Organic Matter Removal on Physical and Chemical Parameters from summer surveys at Woodhill, Tarawera, Kinleith and Golden Downs combined

	FH Moisture (kg/kg)	FH Mass (kg/m^2)	FH Density (kg/m^3)	FH % C (g/100g)	FH % N (g/100g)	FH Mass C (kg/m^2)	FH Mass N (kg/m^2)	FH C/N	Soil Moisture (kg/kg)	Soil pH	Soil % C (g/100g)	Soil % N (g/100g)	Soil C/N
SUMMER 2002													
FF	0.56 **a**	2.04 **a**	98.97	35.52 **a**	1.06	0.63 **a**	0.02 **a**	34.72 **a**	0.24 **a**	5.14 **a**	5.53 **a**	0.25 **a**	23.69 **a**
	(0.03)	(0.38)	(11.81)	(1.78)	(0.06)	(0.11)	(0.00)	(1.69)	(0.02)	(0.06)	(0.72)	(0.03)	(1.07)
WT	0.61 **b**	3.23 **b**	99.64	39.13 **b**	1.13	1.15 **b**	0.03 **b**	36.31 **a b**	0.29 **b**	4.95 **b**	8.65 **b**	0.36 **b**	24.79 **a b**
	(0.02)	(0.55)	(10.10)	(1.76)	(0.05)	(0.18)	(0.01)	(2.30)	(0.03)	(0.06)	(1.07)	(0.04)	(0.88)
SO	0.61 **b**	4.43 **c**	108.36	42.02 **c**	1.13	1.77 **c**	0.05 **c**	39.04 **b**	0.29 **b**	4.85 **b**	9.46 **b**	0.39 **b**	26.07 **b**
	(0.02)	(0.62)	(7.63)	(1.43)	(0.04)	(0.22)	(0.01)	(2.21)	(0.03)	(0.07)	(1.19)	(0.04)	(1.53)
SUMMER 2003													
FF	0.35	1.46 **a**	146.76	46.80	1.21	0.68 **a**	0.02 **a**	40.71	0.14 **a**	NA	NA	NA	NA
	(0.04)	(0.17)	(11.62)	(0.89)	(0.05)	(0.08)	(0.00)	(2.20)	(0.02)				
WT	0.37	2.04 **b**	148.10	46.65	1.28	0.96 **b**	0.03 **b**	38.08	0.16 **a**	NA	NA	NA	NA
	(0.03)	(0.20)	(10.77)	(0.71)	(0.04)	(0.10)	(0.00)	(1.71)	(0.02)				
SO	0.39	2.59 **c**	140.29	47.10	1.25	1.21 **b**	0.0.3 **b**	39.05	0.22 **b**	NA	NA	NA	NA
	(0.04)	(0.22)	(8.79)	(0.72)	(0.04)	(0.10)	(0.00)	(1.62)	(0.03)				
COMBINED													
FF	0.46 **a**	1.75 **a**	122.86	41.16 **a**	1.13 **a**	0.65 **a**	0.02 **a**	37.71	0.19 **a**	NA	NA	NA	NA
	(0.03)	(0.21)	(8.84)	(1.23)	(0.04)	(0.07)	(0.00)	(1.44)	(0.02)				
WT	0.49 **a b**	2.64 **b**	123.87	42.89 **a b**	1.21 **b**	1.05 **b**	0.03 **b**	37.19	0.22 **b**	NA	NA	NA	NA
	(0.03)	(0.30)	(8.02)	(1.06)	(0.04)	(0.10)	(0.00)	(1.44)	(0.02)				
SO	0.50 **b**	3.51 **c**	124.33	44.56 **b**	1.19 **b**	1.49 **c**	0.04 **c**	39.05	0.25 **c**	NA	NA	NA	NA
	(0.03)	(0.35)	(6.17)	(0.87)	(0.03)	(0.13)	(0.00)	(1.37)	(0.02)				

NA indicates treatment was not applied, or a given analysis was not performed
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

organic matter removal interactions were calculated for the 2002, 2003 and combined years data sets (refer S. App. 1.9.1 – 1.9.3). In 2002 the effects of the organic matter removal treatments on the FH moisture content, FH mass, percentage of nitrogen in the FH litter and carbon: nitrogen ratio of the FH litter varied across the four sites, as did the total masses of carbon and nitrogen contained in the forest floor FH litter. These variations in the responses of the FH parameters across the sites were not observed statistically in 2003, but the soil moisture content responded differently to the organic matter removal treatments at different sites. The combined data for 2002 and 2003 produced seven significant site: organic matter removal treatment interactions, in the FH moisture content, FH mass, FH density, percentage of nitrogen in the FH litter, total masses of carbon and nitrogen in the FH litter and in the carbon: nitrogen ratio of the FH litter.

2.4: DISCUSSION

As the aim of the work in this chapter was to identify the effects of the fertilisation and the organic matter removal treatments on the properties of the FH litter layer and soil, the effects and interactions between these two treatment types will be the focus of this discussion. However, the variation between site, year and season will also be discussed, although not in the same detail.

2.4.1: Spatial and Temporal Variations in the Physical and Chemical Parameters

Site Variations

The identification of significant variations in the physical and chemical parameters across the LTSP sites was in agreement with earlier studies into the characteristics of the litter and soil in pine plantations, which report similar variability in the characteristics of the soil and forest floor litter, describing significant variations in physical conditions, moisture and nutrient content and soil pH values (Florence and Lamb, 1974; Lamb and Florence, 1975; Goh and Heng, 1987; Sanger *et* al., 1996; Kavvadias *et al*., 2001). In these studies, the differences in the soil and litter parameters were attributed to variations in the characteristics of the sites, such as stand age, soil properties, and the prevailing climatic conditions, and these differences were similarly considered to be the source of the significant inter-site variability found in this study. Rainfall levels varied considerably between the different sites over the course of the sampling rounds (refer Appendix One), potentially influencing soil and FH litter moisture content, as has been found previously (Salamanca *et al*. 2003).

Annual Variations

Some of the significant annual variation in the physical and chemical parameters at the LTSP sites could be explained by the variation in rainfall, as summer 2003 was substantially drier than 2002 at all six LTSP sites (Appendix One), and this was particularly evident in the significant decreases in the mean moisture content values of the soil and FH litter at all sites (Salamanca *et al*. 2003). This reduction in available moisture may have also influenced other parameters of the forest floor indirectly, as decreased moisture levels have been reported to reduce litter production (Witkamp and van der Drift, 1961) decrease the rates of leaching of water soluble substances from litter (Nykvist, 1959; Berg and Staaf, 1981), diminish rates of stemflow and throughfall (Parker, 1983) and decrease rates of litter decomposition (Meentemeyer, 1978; Brown *et al*., 1995). Additionally, the trees at the Kinleith site were thinned between the 2002 and 2003 sampling rounds, resulting in the addition of a substantial mass of needles and coarse woody debris to the plots. This was reflected in the increased FH mass and FH density values at Kinleith in 2003.

Seasonal Variations

The significant seasonal variations in the moisture content of the FH litter and soil at Woodhill, Berwick and Golden Downs was most likely caused by the substantial drop in temperature that occurred at these sites in winter (Appendix Two), as this would have limited rates of evaporation (Meentemeyer, 1978). Rainfall over the three months prior to sampling was greater in winter only at Golden Downs in both years and at Woodhill in 2002, and rainfall at Berwick was considerably decreased in winter (Appendix One), suggesting that this factor did not influence the seasonal moisture content variations as uniformly as the drop in temperature. The decreased FH litter mass in winter was considered the result of the litterfall patterns displayed by *Pinus radiata*, as peak litterfall occurs in August and November (Lamb and Florence, 1975), providing ample time for the fresh litter to enter the FH layer for the summer sampling rounds, but not the winter sampling rounds, as the litterfall would have been too fresh to be included in the collections.

2.4.2: Effects of Fertilisation and Organic Matter Removal Treatments on Physical and Chemical Parameters

FH Mass

The mean FH masses for all sites combined in summer 2002 and 2003 for fertilised and unfertilised plots were 3.22 kg/m^2 and 2.09 kg/m^2 (Table 2.10). Across the individual sites, the FH mass in unfertilised plots ranged from 7.28 kg/m^2 at Woodhill to 0.63 kg/m^2 at Golden Downs. In a study based in *P. radiata* plantations of various ages located in the South Island of New Zealand, the mass of air dried FH litter present on the forest floor was found to vary from 7.3 kg/m^2 (Golden Downs plantation, 9 years old) to 0.9 kg/m^2 (Hochstetter plantation, 9 years old) and the mean FH mass was calculated to be 2.6 kg/m^2 (Goh and Heng, 1987). These figures agree well with the values generated for mean FH mass in unfertilised plots of the LTSP sites used in this study.

The increases in FH litter mass in response to fertilisation found in this study are in agreement with the results of another study, in which the application of phosphorus to 8, 20 and 25 year old *P. elliottii* stands was found to statistically increase the mass of forest floor litter in the youngest and oldest stands (Wienand and Stock, 1995). The increased FH mass may have been caused by decreased rates of litter decomposition in the fertilised plots, as has been previously reported (Magill and Aber, 1998), but as litter decomposition rates were not examined in this study, this cannot be commented on with any validity. Fertiliser application has also been associated with increased litter production in forests (Vitousek, 1982, Wienand and Sytock, 1995), which would have also increased the mass of litter on the forest floor. Litter production at the six LTSP sites was measured over the course of this study, and the effects of fertilisation will be discussed in a later chapter.

Although not always statistically significant, the general trend of increased organic matter removal at site establishment resulting in decreased FH litter mass was strongly evident across the LTSP sites (Tables 2.4 – 2.9). These differences in the FH litter mass between the treatment plots clearly indicated that the LTSP sites were still significantly influenced by the organic matter removal treatments. Additionally, as the treatment effects were still evident up to 17 years after application, the mean FH litter masses in the FF, WT and SO plots at each site potentially will not converge on equivalent values for a considerable length of time, if at all, before the current rotation is harvested and the organic matter treatments are reapplied at the sites.

FH Density

The range of FH density values in unfertilised plots presented in this study agrees well with those reported by Goh and Heng (1987) in a study of soil and forest floor characteristics in five *P. radiata* plantations in the South Island of New Zealand. The means of the air dried FH density values determined by Goh and Heng at the different plantations varied from 60 to 170 kg/m^3, and the vast majority of the FH density values calculated in this study fall within this range.

Fertiliser addition did not consistently affect the density of the FH litter layer at the LTSP sites. The only mechanism by which the fertilisation treatment could have altered the density of the FH litter was by altering the relative proportions of low and high density material in the FH litter layer, but as few significant effects of fertilisation were detected, it was evident that this did not occur consistently, if at all. A search of the relevant literature did not uncover any previous research into the effects of fertilisation on FH litter density, so these results cannot be compared to any other work at this time.

Some significant differences in the density of the FH litter sampled from the different organic matter removal treatment plots were anticipated, as it was posited that the retention of branches and other coarse woody debris generated during the harvest of trees in the SO treatment plots may still have proportionally increased FH litter density. However, this effect was not consistently observed at the LTSP sites, suggesting that any initial differences in FH litter density between the organic matter removal treatment plots may have been mitigated over time. This process may have been accelerated by the thinning treatments that occurred at all sites, as this resulted in the addition of coarse woody debris to all plots (Ganjegunte *et al.*, 2004).

FH Moisture Content

The moisture content of the FH litter layer in forest plantations in coastal British Columbia was found to vary from 36.5% to 51.1% with site, and from 37.7% to 53.4% with species, although none of the species under study were pine (Grayston and Prescott, 2005). These values are similar to those reported in this study, but it should be noted that the mean annual rainfall at the sites of Grayston and Prescott (2005) was 3943mm, substantially greater than at any of LTSP sites (Table 1.2). Little other data regarding the moisture content of FH litter in forest plantations is currently available, so further comparison cannot be made.

The significant increases in FH moisture content resulting from fertilisation and, to a lesser extent, in the plots where organic matter had been retained (with the exception of Berwick, where increased organic matter removal resulted in increased moisture content in the FH litter), were unlikely to have been caused directly by either treatment. As both these treatments were found to influence the mass of FH litter present in the plots, it was postulated that the moisture content of the FH litter was correlated with the mass of FH litter present on the forest floor in each plot, based on the ability of a greater mass of litter to insulate itself and hold more moisture, as has been suggested previously (Bååth, 1980; de Santo *et al*., 1993; Prescott *et al*., 2000). Reasonably strong positive correlations were found between the mass of FH litter and the FH litter moisture content at Burnham and Golden Downs in both summer sampling rounds, and also at Kinleith in summer 2003, but at the other sites the correlation was weaker in summer, and no correlations were evident at any site in winter (Appendix Three). Some of this site and seasonal variation was be explained by the differences in the amounts of rainfall at the sites during and prior to the sampling rounds (Appendix One), as high levels of rainfall tended to saturate the FH litter, negating any treatment effects on moisture content from being observed, but when less rainfall occurred, the plots with greater FH litter masses had a increased capacity to retain moisture, and hence were found to contain more moisture during the sampling rounds. However, negative correlations were calculated between FH litter mass and moisture content at Berwick in both summer sampling rounds. This was consistent with the statistical differences in FH litter mass and moisture content between the organic matter removal treatment plots at this site, but currently cannot be explained.

Percentage of Carbon in FH Litter

The percentage of carbon in the FH litter layer collected in unfertilised plots varied from 21.2% at Woodhill in summer 2002 to 49.7% at Golden Downs in summer 2003, and the mean carbon content for both years across the six sites was 42.23%. These figures agree reasonably well with those reported in a previous study based at the Woodhill, Tarawera and Kinleith sites, in which the mean carbon content of the forest floor litter in the unfertilised plots was found to be 19.8%, 37.8, and 39.5% respectively (Smith *et al*., 2000), although it should be noted that freshly fallen litter on the forest floor was included, and the litter was collected 5 years after each site was established, substantially earlier than in this study.

Fertilisation tended to increase the percentage of carbon in the FH litter, although the increases were not consistently statistically significant. Previous investigations into forest floor nutrient levels have detected similar responses to fertilisation, as the carbon content of the forest litter and humus was either unaffected by fertiliser applications (Smith *et al*., 2000; Jandl *et al*., 2003) or statistically increased (Prescott *et al*., 2000; Sjöberg *et al*., 2004). It has been suggested that the increases in carbon content may be the result of interactions between the fertiliser and carbon compounds in the litter itself or alterations to the structure and activity of the decomposer community, and the latter point will be discussed in the following chapters (Prescott *et al*., 2000; Sjöberg *et al*., 2004).

FH litter carbon content at the LTSP sites tended to decrease with increasing organic matter removal, and a similar effect was reported in Scots pine and Norway spruce plantations, in which the carbon content of the forest floor litter in WT plots was decreased when compared to SO plots up to 16 years after the treatments were applied (Olsson *et al*., 1996a). At Woodhill, Tarawera, Kinleith and Golden Downs combined, all three treatments were statistically distinct in 2002, and the mean carbon content for the FF treatment plots was statistically less than that of the SO plots for 2002 and 2003 combined (Table 2.12). The harvesting residues retained in the SO plots, and the coarse woody debris present in the FH litter of the SO and WT treatment plots would have added substantially to the mass of carbon on the forest floor compared to the FF treatment plots, and due to the recalcitrant nature of coarse woody debris (Harmon *et al*., 1986; Ganjegunte *et al*., 2004), a proportion would most likely still be present in the FH litter layer at the time of sampling, resulting in these differences.

These finding also have potential implications for the effects of fertilisation and organic matter treatments on carbon storage in plantations forests, and this will be considered later in conjunction with the discussion regarding the effects of the treatments on soil carbon pools.

Percentage of Nitrogen in FH Litter

The percentage of nitrogen in the FH litter in unfertilised plots varied from 0.59% at Woodhill in the summer 2002 sampling round to 1.44% at Kinleith in summer 2003, and the mean percentage of nitrogen in unfertilised plots across all sampling rounds was 1.04%. These values were greater than those reported by Smith *et al*. (2000) for unfertilised plots at Woodhill, Tarawera and Kinleith, but as previously noted, the entire forest floor litter layer was sampled, and additional fertiliser application was carried out at these sites before the current study was performed, potentially explaining the differences in the FH litter layer nitrogen content.

The significant increases in FH litter nitrogen content in response to fertilisation agrees with the results of earlier studies (Smith *et al*. 2000; Jandl *et al*., 2003), which reported substantial increases in the mean percentage of nitrogen in forest floor litter collected from fertilised plots. The potential mechanisms for this increase include increased concentrations of nitrogen in foliar litter in the fertilised plots (Smith *et al*., 2000), and this will be discussed in greater detail in a later chapter.

The FH litter nitrogen content tended to decrease with increasing levels of organic matter removal, but this was not observed uniformly across the sites and sampling rounds, and was not considered to be a strong effect. Other studies reporting the effects of organic matter removal on FH litter nitrogen content show similar variability, as some report decreased nitrogen content with increasing organic matter removal (Ohtonen *et al*., 1992; Olsson *et al*., 1996a), while Smith *et al*. (2000), working at Woodhill, Tarawera and Kinleith reported that the lowest mean litter nitrogen content were found in the WT or SO plots, not the FF treatment plots. As with the fertilisation treatment, some of the explanation for the sporadic decreases in nitrogen content may be related to the effects of organic matter removal on foliar nitrogen content, which has been found to be decreased by organic matter removal in some cases (Smith *et al*., 2000), and will be discussed in a later chapter.

Carbon and Nitrogen masses in the FH litter layer

As the masses of carbon and nitrogen present in the FH litter layer were products of the FH litter mass and nutrient content values, significant treatment effects on either FH litter mass or nutrient content were anticipated to influence the total masses of carbon and nitrogen in the FH litter layer of the LTSP sites. Similar results regarding the effects of organic matter removal treatments were reported by Hyvöven *et al*. (2000), using mathematical models to determine the effects of the retention or removal of harvest debris on the forest floor nutrient levels during the subsequent rotations. In this study the retention of harvest debris (equivalent to SO harvesting) was calculated to increase the masses of carbon and nitrogen in the forest floor by 50% and 30% in *Picea abies* plantations compared to the harvest debris removal (WT harvesting) plots, and by 100% and 70-80% respectively in *P. sylvestris* plantations (Hyvöven *et al*. 2000).

FH Litter Carbon: Nitrogen Ratio

In the unfertilised plots, the mean value of the FH litter layer carbon: nitrogen ratio ranged from 33.6 at Tarawera in 2002 to 55.4 at Golden Downs in the same year, and the mean across all six sites in 2002 and 2003 was 41.7. Using the data provided by Smith *et al*. (2000), the mean litter carbon: nitrogen ratios in the unfertilised plots at Woodhill, Tarawera and Kinleith several years earlier were calculated to be 48.4, 42.1 and 42.5 respectively, similar to those found in this study. However, in an earlier study based in several *P. radiata* plantations in South Australia, the carbon: nitrogen ratio of the F layer litter was substantially lower, varying from 11.7 to 19.6, although it should be noted that H layer litter was not included, and the *P. radiata* stands were significantly older (Lamb and Florence, 1975).

Fertilisation caused a relatively consistent decrease in FH litter carbon: nitrogen ratio, although this was not always observed statistically. Based on the results presented by Smith *et al*. (2000), the carbon: nitrogen ratios at Woodhill, Tarawera and Kinleith were calculated to be 30%, 6% and 26% lower respectively in the fertilised plots five years after the fertilisation treatments commenced, agreeing with the trend in this study. As discussed above, the fertilisation treatments tended to increase the percentage of carbon and nitrogen in the litter, but the increases in the nitrogen content of the litter were substantially larger, explaining the generally lower carbon: nitrogen ratio of FH litter collected in the fertilised plots.

Organic matter removal did not consistently influence the carbon: nitrogen ratio of the FH litter. This result disagrees with those of a study in Scots pine and Norway spruce plantations, comparing SO and WT harvest treatments up to 16 years after felling (Olsson *et al*., 1996a), which reported significantly greater carbon: nitrogen ratios in the H layer litter collected from WT plots, although it should be noted that F litter was not included in the study of Olsson *et al*. (1996a). Prior to sampling, it had been proposed that the carbon: nitrogen ratio of the FH litter in the LTSP sites may have been lowest in the WT plots, due to the removal of the woody harvest debris and the retention of the forest floor. However, as this was not observed statistically at any site, it was concluded that the intensity of this effect (if it occurred at all) had been diminished over time, due to litterfall and thinning residues. This conclusion was substantiated to a degree by Smith *et al*. (2000), who determined that the lowest mean carbon: nitrogen ratios were found in the litter layer of the WT plots at Woodhill, Tarawera and Kinleith five years after the organic matter removal treatments were applied, but the statistical significance of the differences is unknown, and as the entire litter layer was sampled, the results presented in this study cannot be considered to support this theory.

Soil Moisture Content

In unfertilised plots the mean moisture content in the top 25mm of the soil ranged from 6% at Tarawera in summer 2003 to 46% at Kinleith in summer 2002, and the mean of both summer sampling rounds across the six sites was 22%. In the winter sampling rounds at Woodhill, Berwick and Golden Downs, the mean soil moisture content across both years was 30%.

Fertilisation had very little effect on the moisture content of the soil samples. Similar results were reported in a study in a Loblolly pine plantation, in which the moisture content in the top 100mm of soil was statistically unaffected by the addition of nitrogenous fertiliser up to 25 months after the addition of the fertiliser (Gurlevik *et al*., 2004).

As was the case with the FH litter moisture content, the significant decreases in soil moisture content associated with increasing levels of organic matter removal at the LTSP sites were postulated to be the results of decreased FH litter mass, as this has the potential to decrease water retention (Prescott *et al*., 2000). However, analysis of the correlation data (Appendix Three) indicated that the relationship between soil moisture content and FH litter mass was weakly positive at best (highest r^2 value was 0.27), and the correlation was negative in several cases. Additionally, these results do not agree with those of Piatek and Allen (1999), who reported that soil moisture content did not differ significantly between SO and WT plots in a Loblolly pine plantation 14 years after the treatments were established. Consequently, it was suggested that other factors related to increased organic matter removal influenced the soil moisture content, but this was not investigated further due to time constraints.

Soil pH

In unfertilised plots the pH of the top 25mm of soil ranged from 4.37 at Berwick to 5.16 at Kinleith, and the mean across all sites was 4.93. These values were lower than those reported in pine and mixed plantations in other studies (Ohtonen *et al*., 1992; Thirukkumaran and Parkinson, 2002; Lee and Jose, 2003), but in these cases soil samples were taken to a greater depth, and the site characteristics such as soil type varied substantially, accounting for some of this variation.

Soil pH tended to decrease in response to fertilisation, and similar results have been reported previously in other fertilised plantations (Ballard, 2000; Smethurst *et al*., 2001). It has been suggested that this phenomenon is the result of the release of hydrogen ions during nitrification induced by high levels of available nitrogen (Ballard, 2000). However, as soil pH decreases were not observed in a number of other studies (Ohtonen *et al*., 1992; Thirukkumaran and Parkinson, 2002; Lee and Jose, 2003), and indeed was not uniformly observed in this study, other factors, such as initial site characteristics and the type, quantities and rate of fertiliser addition, are important in determining the response of soil pH to fertilisation.

The lack of significant differences in soil pH between the SO and WT treatment plots is in agreement with previous research (Olsson *et al*., 1996b), but across the Woodhill, Tarawera, Kinleith and Golden Downs plots the soil pH in the FF plots was significantly greater than that in the WT and SO plots.

The mechanism by which the organic matter removal treatments influenced soil pH was unknown, but it was speculated that the differences in the mass of nutrients, particularly nitrogen and the forms in which it was present in the soil, may have influenced soil pH, although this cannot be substantiated.

Percentage of Carbon in Soil

The carbon content of the top 25mm of soil in unfertilised plots was lowest at Woodhill (mean value of 0.7%) and highest at Golden Downs (mean value of 14.2%), and across all sites the mean percentage of carbon in the soil samples was 7.6%. The range of values in this study tended to be lower than those reported by others working in plantation forests (Piatek and Allen, 1999; Gurlevik *et al*., 2004; Sjöberg *et al*., 2004), but some of this variation may be explained by the differences in soil sampling depth, as soils in this study were taken to 25mm, rather than 100mm or 150mm, as occurred in other studies.

Although fertilisation significantly increased the soil carbon content at Woodhill and Tarawera, the lack of statistical increases at the other LTSP prevented a significant increase across all sites from being calculated. This variability is matched by the findings of previous studies. Gurlevik *et al*. (2004), reported that soil carbon content in a Loblolly pine plantation, sampled to a depth of 100mm, was not affected by applications of nitrogen and phosphorus, but in another study soil carbon content in the top 25cm of soil was significantly increased by fertilisation twenty years after application (Jandl *et al*., 2003). In other studies in which soil carbon content has increased in response to fertilisation, it has been concluded that the increases were driven by decreased rates of respiration and organic matter decay, resulting in increased carbon storage (Magill and Aber, 1998; Nohrstedt, 2001). Fertilisation was found to significantly influence soil microbial community properties at both Woodhill and Tarawera, which will be discussed in later chapters, and this mechanism was also considered to be responsible for the increases in carbon content at these sites.

The decrease in mean soil carbon content resulting from only the FF organic matter agreed with the findings of previous studies, which reported significant decreases in soil carbon content in FF treatment plots when compared to SO plots after 7 years in a second rotation *P. radiata* plantation

(Ballard, 1978), and no significant differences between SO and WT plots after fifteen years in a Loblolly pine plantation (Piatek and Allen, 1999). The explanation for the substantial decrease in soil carbon content in the FF plots may be related to retention of the FH litter layer, as this was common to the WT and SO treatments, but not the FF treatment. The carbon in the organic matter comprising the FH litter would have been gradually assimilated into the soil (Swift *et al*., 1979), but the removal of this layer would prevent this input from occurring, resulting in the diminished concentration of carbon.

These results, and the findings regarding the amount of carbon in the FH litter, are also of interest with regard to carbon sequestration in forests, which is a currently an issue of some importance (Oliver *et al*., 2004). The significant increases and decreases in carbon content in response to fertilisation and organic matter removal respectively indicate that site management can measurably alter carbon sequestration over the life of the rotation. Consequently, to more accurately understand the impact of plantation forestry on carbon balance models, and to better predict the sustainability of site management regimes, it is apparent that the potential differential effects of management practices, such as fertilisation and organic matter removal, on forest floor and soil carbon storage must be accounted for.

Percentage of Nitrogen in Soil

The percentage of nitrogen in the soil samples collected in unfertilised plots varied considerably, from 0.02% at Woodhill to 0.48% at Golden Downs. The mean across the six sites was calculated to be 0.33%. As was the case with soil carbon content, this range of values was considerably lower than those presented in other studies (Piatek and Allen, 1999; Gurlevik *et al*., 2004; Sjöberg *et al*., 2004), and as before it was suggested that the differences in soil sampling depths may be responsible for some of the variation.

Fertilisation increased the percentage of nitrogen in the soil sample at all sites, although the magnitudes of the increases were not consistently significant. Similar results have been reported in the literature, as Gurlevik *et al*. (2004) determined that long term nitrogen additions increased the percentage of nitrogen in soil samples, but not significantly, while Jandl *et al*.

(2003) found that soil nitrogen content was statistically increased by an extensive fertilisation regime twenty years earlier. The increased soil nitrogen content in fertilised plots may have been caused directly by the retention of the added nitrogen in the soil, but the increases may also be related to increased inputs of nitrogen from foliar litter, which will be discussed in a later chapter.

The trend towards decreased soil nitrogen content only in the FF organic matter removal treatment plots was in agreement with previously published studies. Piatek and Allen (1999) found no significant differences between WT and SO treatments, and lower soil nitrogen content in FF plots than in SO plots has also been reported (Ballard, 1978; Ohtonen *et al*., 1992), although the differences were not statistically significant in the 1992 study. The explanation for the reduced soil nitrogen content in the FF plots was considered to be the same as for the soil carbon – that the removal of the FH litter layer prevented a significant input of nitrogen into the soil, resulting in the decreased percentage of nitrogen in the soil (Swift *et al*., 1979, Attiwill and Adams, 1993).

Soil Carbon: Nitrogen Ratio

The carbon: nitrogen ratio of the soil samples collected in unfertilised plots ranged from 16.3 at Burnham to 37.4 at Woodhill, and the mean ratio across the six sites was calculated to be 24.9. These ratios agreed well with those reported previously for unfertilised soils in pine and mixed pine plantations (Piatek and Allen, 1999; Gurlevik *et al*., 2004; Sjöberg *et al*., 2004), although the actual values for carbon and nitrogen tended to be lower, as discussed above.

Across all sites, the mean soil carbon: nitrogen ratio was 21.11 in fertilised plots, significantly lower than that in unfertilised plots. Decreases in soil carbon: nitrogen ratios in response to fertilisation have been reported previously, although the magnitudes of the decreases were not always statistical (Gurlevik *et al*., 2004; Sjöberg *et al*., 2004). These decreases in mean soil carbon: nitrogen ratios were considered to be the result of the increases in soil nitrogen content, which were discussed earlier.

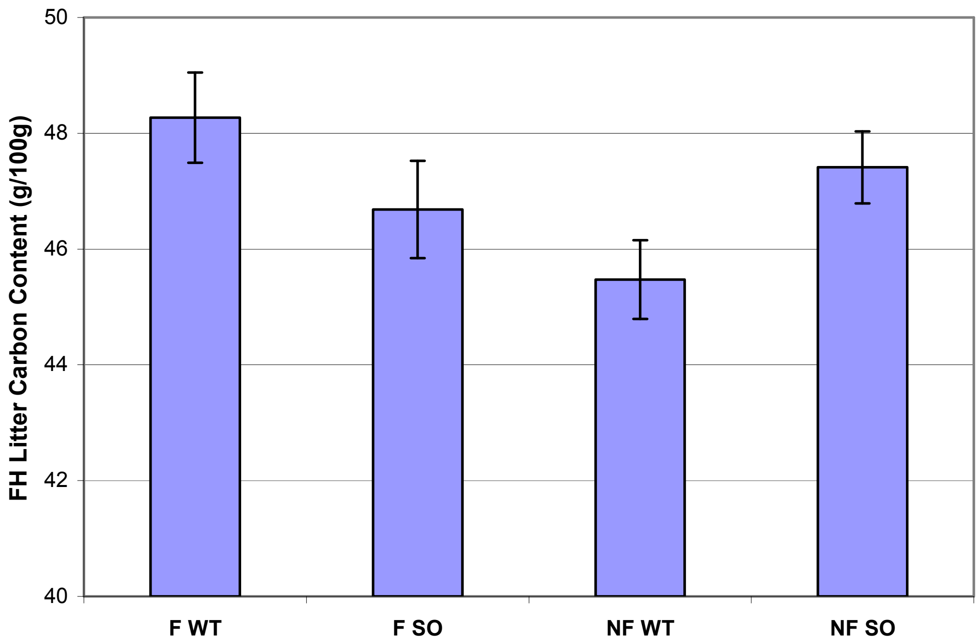
Carbon: nitrogen ratios tended to be lower in the FF treatment plots than in the SO treatment plots. The decreases in carbon: nitrogen ratios in the

FF treatment sites were driven by the reduction in soil carbon content resulting from the organic matter removal treatments. Although soil nitrogen content was also decreased by the FF treatment, the decrease in soil carbon content was greater, resulting in the overall lowering of the carbon: nitrogen ratio at these sites. No comparative data is available, other than a study comparing SO and WT treatments, which found soil carbon: nitrogen ratios were not influenced (Piatek and Allen, 1999).

2.4.3: Significant Fertilisation: Organic Matter Removal Treatment Interactions

Across all sites in summer 2003, FH litter carbon content was significantly greater in fertilised WT plots than in unfertilised WT plots, while no effect of fertilisation on the SO plots was determined (S. App. 1.8.2). Furthermore, the carbon content in unfertilised SO plots was statistically greater than that in unfertilised WT plots, whereas there was no significant difference between fertilised SO and WT plots (refer Figure 2.4).

Figure 2.4: Effect of Treatments on the Percentage of Carbon in the FH Litter at all Sites in Summer 2003



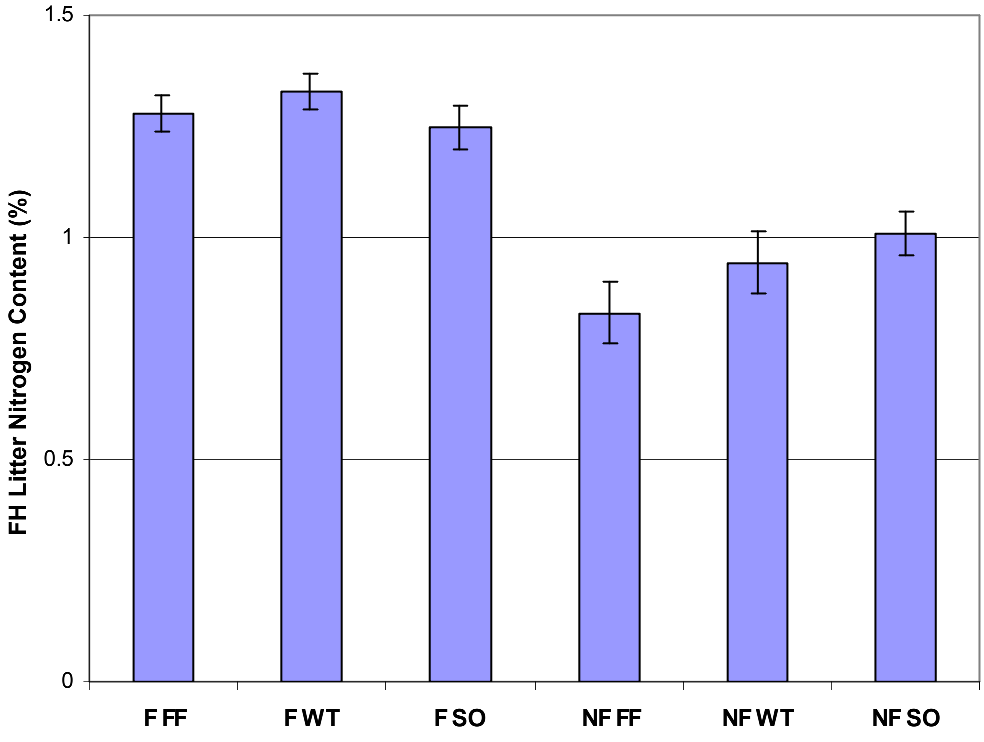
Error bars indicate the standard error of the mean

This effect was repeated in the results of the data analysis for all three organic matter removal treatments across Woodhill, Tarawera, Kinleith and

Golden Downs (S. App. 1.9.2), but only for the WT treatment, as the FF treatment was not differentially affected by fertilisation.

As described earlier, the increased FH litter carbon content in the fertilised treatment plots was potentially the result of decreased decay rates (Magill and Aber, 1998; Nohrstedt, 2001), and inspection of Figure 2.4 suggests that consequently fertilisation did offset the differences in FH litter carbon content between the WT and SO treatments. However, as the FF treatment plots were not similarly influenced, and no interaction at all was detected in summer 2002 (S. App. 1.8.1), this single significant interaction does not confirm that fertilisation can mitigate the effects of organic matter removal on this parameter of the forest floor environment.

Figure 2.5: Effect of Treatments on the Percentage of Nitrogen in the FH Litter at Woodhill, Tarawera, Kinleith and Golden Downs in Summer 2002



Error bars indicate the standard error of the mean

The effect of the organic matter removal treatments on the percentage of nitrogen in the FH litter was also significantly influenced by fertilisation in one instance (S. App. 1.9.1). Across the Woodhill, Tarawera, Kinleith and Golden Downs sites, the mean FH litter nitrogen content in unfertilised FF plots was significantly less than that in the unfertilised SO plots, but in fertilised plots the percentage of nitrogen in the FH litter did not differ significantly across the three organic matter removal treatments (Figure 2.5).

Fertilisation had the effect of introducing additional nitrogen to the FH litter, and this negated the nitrogen content gradient established by the different levels of organic matter removal in the unfertilised plots. However, this effect was only significant in 2002, and this inconsistency prevents any comprehensive conclusions regarding the capacity of fertilisation to counteract the effects of organic matter removal on FH litter nitrogen content.

A few site-specific fertilisation: organic matter removal interactions were calculated in the analysis of the physical and chemical environment data, but none were observed consistently across multiple sampling events. Consequently, none of these interactions were considered to indicate that fertilisation was mitigating the effects of organic matter removal at the LTSP sites.

2.4.4: Conclusions

The results of this chapter have confirmed the majority of the hypotheses proposed in the introduction of this chapter. Fertilisation significantly increased the FH litter mass, FH litter and soil moisture content, and FH litter and soil nitrogen content. Carbon: nitrogen ratios were also decreased by fertilisation, as was soil pH. Increasing levels of post-harvest organic matter removal proportionally decreased the masses of FH litter present on the forest floor at the time of sampling, and increasing organic matter removal also decreased FH litter and soil moisture content. The nitrogen content of the FH litter and soil was lowest in the FF treatment plots, and carbon: nitrogen ratios were lower in the plots with the greatest amount of organic matter removal. The last hypothesis was not confirmed, however, as the analysis of the interactions between the fertilisation and organic matter removal treatments at the LTSP did not produce consistent evidence that fertilisation was influencing the measured physical and chemical parameters to counter the effects of the organic matter removal treatments.

Consequently, it was determined that fertilisation and post-harvest organic matter removal have substantially altered the physical and chemical environment of the forest floor in these six plantations. The fertilisation treatments occurred regularly at all six sites, and the effects of fertilisation may diminish after the cessation of fertilisation, but based on the results presented in this chapter, it was theorised that the organic matter removal treatments may continue to influence the characteristics of the forest floor for a considerable length of time, as these treatments were applied at site establishment, were not reinforced in any way, and were still producing highly significant effects upon various parameters of the forest floor between 8 and 17 years after application.

CHAPTER THREE: EFFECTS OF FERTILISATION AND ORGANIC MATTER REMOVAL ON MICROBIAL BIOMASS

3.1: INTRODUCTION

As discussed in Chapter One, the activities of the plant litter and soil microbial community are crucial to the processes that maintain terrestrial ecosystems (Wardle, 1992; Brussaard *et al*., 1997; Kennedy and Gewin, 1997; Wall and Moore, 1999). Consequently, it is important to understand how plant litter and soil microbial communities respond to alterations in the physical and chemical environmental, as changes to the characteristics of the microbial community may influence the processes that the community performs (Vestal and White, 1989; Wardle *et al*., 2001; Li *et al*., 2004), and this in turn has significant implications for the design and implementation of sustainable forestry practices (Brussaard *et al*., 1997; Kennedy and Gewin, 1997; Noble and Dirzo, 1997; Wall and Moore, 1999).

Forest floor microbial biomass can vary substantially in response to natural conditions and events. A number of studies across a range of forests have reported substantial seasonal variations in plant litter and soil microbial biomass (Bååth and Söderström, 1982; Díaz-Raviña *et al*., 1994; Bohlen *et al*., 2001), and this variation has been correlated to the moisture level at the time of sampling (Srivastava, 1992). Spatial variation in microbial biomass, both laterally across the surface of a site and vertically through the litter and soil layers have also been reported (Bååth and Söderström, 1982; Bohlen *et al*., 2001; Agnelli *et al*., 2004; Grayston and Prescott, 2005), and it has been suggested that these variations are related to differences in the litter and soil characteristics, such as the availability of nutrients and moisture (Bohlen *et al*., 2001, Agnelli *et al*., 2004).

Microbial biomass has also been found to be a sensitive indictor of anthropogenic disturbances to the litter layer and soil environment (Wardle, 1992), and measurements of this parameter of the microbial community can provide information in two ways. Firstly, it provides evidence that a given treatment or event has significantly altered the conditions in litter and soil environment (Bååth, 1980; Lee and Jose, 2003; Li *et al*., 2004), and can also be used to evaluate the progression of restoration programs in areas where physical or chemical disturbances have occurred in the past, such as at former mining sites (Insam and Domsch, 1988; Bentham *et al*., 1992). Secondly, as microbial biomass levels have been correlated with aspects of nitrogen cycling and the decay of plant litter (Wardle, 1992; Allen and Schlesinger, 2004; Blazier *et al*., 2005), measurements of litter and soil microbial biomass may also indicate how the disturbance or event may impact on nutrient cycling processes, such as rates of nitrogen mineralisation by the microbial community.

Numerous studies into the effects of agricultural, silvicultural and other treatments on microbial biomass are available. A review of the literature was presented by Wardle (1992), reporting that soil microbial biomass was significantly influenced by soil carbon and nitrogen levels, but the nature of the response varied considerably from site to site, as did the response to moisture availability. Soil pH was identified as an important factor, with lower microbial biomass consistently found at sites with lower soil pH values, or where a treatment had resulted in a decrease in soil pH. More recently, studies into the effects of conventional tillage practices on soil microbial biomass in agroecosystems have found that tillage significantly decreased microbial biomass in the upper 5cm of soil across a range of sites (Frey *et al*., 1999; Guggenberger *et al*., 1999). In forest ecosystems, the effects of different levels of soil compaction and organic matter removal have been studied across a number of sites, and in several cases numerical differences in the estimates of microbial biomass have been reported, but statistically significant effects have not been found (Ohtonen *et al*., 1992; Bengtsson *et al*., 1998; Ponder and Tadros, 2002; Li *et al*., 2004). Fertilisation in forest plantations has also been studied, and fertilisation regimes have been found to decrease microbial biomass in FH litter and soil in a 5 year old white pine plantation (Ohtonen *et al*., 1992), and in cottonwood and loblolly pine plantations, soil microbial biomass was found to decrease with increasing levels of nitrogenous fertiliser application (Lee and Jose, 2003).

The purpose of this chapter is to assess the sensitivity of the FH litter microbial biomass and soil microbial biomass to disturbance by determining if the fertilisation and organic matter removal treatments, described in section 1.6.4, have significantly altered the microbial biomass at the six LTSP sites, and if any interaction between the treatments is evident in the results. Furthermore, the microbial biomass values will be considered with regard to the values of the physical and chemical parameters examined in Chapter Two, to determine if any relationship exists between the responses of the forest floor parameters and the FH litter and soil microbial biomass to the fertilisation and organic matter removal treatments. The rates of nitrogen mineralisation by the soil microbial communities will also be assessed, using the samples collected in winter 2003 from Woodhill, Berwick and Golden Downs, to determine if the treatments have had any influence on the rates of nitrogen mineralisation, and if soil microbial biomass was statistically related to nitrogen mineralisation rates, as has previously been suggested in agricultural settings (Olfs, 1993). Consequently, the hypotheses that will be addressed in this chapter are:

1. That fertilisation has significantly decreased the FH litter and soil microbial biomass.
2. That organic matter removal has had no significant effects on FH litter and soil microbial biomass.
3. That any significant responses of FH litter and soil microbial biomass to fertilisation or organic matter removal were statistically related to parameters of the physical and chemical environment.
4. That rates of nitrogen mineralisation were statistically related to soil microbial biomass.

3.2: METHODS AND MATERIALS

The method used to determine the microbial biomass in both the FH litter and soil samples was based on the chloroform fumigation – extraction technique developed by Brookes *et al*. (1985a; 1985b). This technique involves using chloroform to induce lysis of microbial tissue, releasing ammonium and other molecules present in the cytoplasm into the soil. Using the methods of Bremner (1965), the mass of inorganic nitrogen released from the soil microbial biomass can then be determined. The exact methodology used in this study is described below.

3.2.1: Sample Preparation and Fumigation

The FH litter and soil used to determine microbial biomass were subsampled from the bulked fresh samples collected and prepared in each sampling round, as described previously in Section 2.2. From the bulked material from each treatment plot, two FH litter samples of equivalent mass and two soil samples of equivalent mass were weighed into four 250ml flasks. The mass of fresh FH litter placed in the two flasks was not consistent across all sites and sampling rounds, as the moisture content of the FH litter varied substantially, altering the density of litter. In order to maintain the same volume of FH litter and prevent overfilling, the mass of FH litter weighed into the flasks varied from 8g to 15g. The mass of fresh soil weighed into the two flasks also varied with site and sampling round, and ranged from 20g to 25g. One of each of the paired FH litter and soil samples was then randomly chosen to receive the fumigation treatment. These samples were placed in an airtight chamber, in the centre of which was a beaker containing 80ml of alcohol-free chloroform, and boiling chips to facilitate a steady rate of evaporation. Several sheets of tissue paper moistened with double deionised water (ddH_2O) were also placed in the chamber to prevent desiccation. The air in the chamber was removed using a vacuum pump, lowering the pressure and causing the chloroform to boil after approximately 4 minutes. When this boiling was observed, the chamber was sealed, the vacuum was turned off, and then air was allowed back into the chamber. After waiting for the pressure in the chamber to equalise with the outside environment, the vacuum was reapplied, and the entire process was repeated twice more, although after boiling of the chloroform was observed the third time, the chamber was sealed, and not opened again for 24 hours. The remaining FH litter and soil samples were designated as the control samples, and placed in an airtight container with several sheets of tissue paper moistened with ddH_2O to prevent desiccation. The control flasks were left in this container for 24 hours. Fumigated and control flasks were kept at approximately 22^{o}C during the course of the fumigation.

3.2.2: Extraction and Measurement of Ammonium

After 24 hours the fumigated and control flasks were removed from the airtight containers, and 50ml of 2M KCl was immediately added to each flask, completely immersing the FH litter or soil. The flasks were then placed on an orbital shaker for one hour. The liquid in the flasks was filtered through Whatman No. 1 filter paper until 30ml to 40ml of filtrate was collected. 10ml of this filtrate was then measured into a Kjeldhal flask, and was steam distilled with MgO as described by Bremner (1965). The distillate was collected and titrated against 0.025M H_2SO_4, of which 1ml was required to reach the end point of the titre with 70µg of ammonium in solution, indicated by a colour change from aqua to faint pink. Using the volume of 0.025M H_2SO_4 required to reach end point, the amount of ammonium in each sample of filtrate was calculated according to Equation 3.1.

$$A^{mass} = \frac{(T - B) \times 70 \times 5}{1000} \qquad (3.1)$$

where:

A^{mass} is the mass of ammonium in the filtrate in mg

T is the volume of 0.025M H_2SO_4 required to reach end point

B is the volume of 0.025M H_2SO_4 required to reach end point for a blank

The values produced by this formula were then used to determine the concentration of ammonium in the fumigated and unfumigated control samples on a dry weight basis, using Equation 3.2.

$$A^{conc} = \frac{A^{mass}}{S^{mass} \times OD^{conv}} \quad (3.2)$$

where:

A^{conc} is the concentration of ammonium in the sample in mg/gram

A^{mass} is the mass of ammonium in the filtrate in mg

S^{mass} is the fresh mass of FH litter or soil in the flask in grams

OD^{conv} is the factor to convert the mass of the sample to an oven dry (and ash free for FH litter) basis

From these values, the mass of ammonium released from the microbial biomass was calculated by subtracting the naturally occurring concentration of ammonium in the unfumigated control samples from the concentration of ammonium in the fumigated samples. In the literature, this figure is often multiplied by a factor of 2.22 to convert the mass of released ammonium to the total mass of nitrogen extractable from the microbial tissue (Brookes *et al*., 1985a). This conversion was considered to be unnecessary in the context of this study, as the relative proportions of microbial biomass in the different treatment plots would be unaffected by the conversion, and consequently would not influence the statistical analysis of the differences between the treatments levels.

3.2.3: Nitrogen Mineralisation Rate Determination

The procedure used to determine the effects of the treatments on the rate of organic nitrogen mineralisation by the soil microbial community was based on that described by Waring and Bremner (1964). Duplicate samples of 10g of fresh soil from each treatment plot, prepared as described in Section 2.2, were placed into flasks, to which 25ml of ddH_2O was added. The flasks were gently swirled until all of the soil was completely submerged, and one of each pair of replicate samples was sealed with a rubber stopper and incubated at 30^oC for 10 days. 25ml of 4M KCl was added immediately to the unincubated flasks, which were then shaken for one hour, after which time the liquid in the flasks was filtered through Whatman No. 1 filter paper and the filtrate collected. The same procedure was followed for the incubated flasks following the 10 day incubation period.

The ammonium content of the unincubated and incubated soil samples was determined by steam distillation and titration using the method and equations described in Section 3.2.2, and the net rate of nitrogen mineralisation was calculated by subtracting the ammonium content in the unincubated samples from that in the incubated samples on an oven dry basis.

3.2.4: Statistical and Regression Analyses

The statistical analysis of the FH litter and soil microbial biomass data was performed as described previously in Section 2.2.5, as was the analysis of the treatment effects on nitrogen mineralisation rates. The microbial biomass data was subject to multiple stepwise regression (S-PLUS Version 6.0.3 statistical package, Lucent Technologies, Inc.) with the physical and chemical parameter data generated in Chapter Two to determine if any statistically significant relationship between microbial biomass and the environment in the plots was evident. This information was then used to generate models for the microbial biomass values, using the physical and chemical parameters as predictors. The nitrogen mineralisation rate data was compared to the microbial biomass data to determine if there was a statistical correlation between the data sets.

3.3: RESULTS

The FH litter and soil microbial biomass values are presented in terms of the mass of NH_4 extracted from the microbial biomass per kg of oven dry ash free FH litter or oven dry soil, and are therefore a relative estimate of the microbial biomass rather than an absolute value. The effects of the fertilisation and organic matter removal treatments on mean microbial biomass and the nitrogen mineralisation rates are presented in tables, and the terms used to identify the various treatments levels are as follows:

FERT	Fertilised Plots
NO FERT	Unfertilised Plots
FF	Whole-tree harvest plus forest floor removal plots
WT	Whole-tree harvest plots
SO	Stem-only harvest plots

The standard error of the mean (SEM) is given in italics, and any statistical differences in the mean microbial biomass values between the levels of a treatment are indicated by a letter or letters. If no letter is present, the values are indistinct at $\alpha = 0.05$ and there was no statistical difference between the treatment levels. Full summaries of the ANOVA calculations are presented in Statistical Appendix Two (S. App. 2).

The results of the regression model calculations are presented for FH litter microbial biomass and soil microbial biomass at each site in each sampling round, and also across all sites for each sampling round. The statistical significance and degree of variation (r^2) explained by each model is reported, as are the parameters, coefficients and intercepts used to generate the models. The terms used to describe the physical and chemical parameters in the tables are the same as described previously in Section 2.3. In cases where multiple parameters were calculated to be significant predictors of microbial biomass, they are listed in order of importance to the model. The relative importance of each parameter in the combined sites models is also reported.

3.3.1: Response of FH Litter Microbial Biomass to Fertilisation and Organic Matter Removal Treatments at the Individual LTSP Sites

Table 3.1: Effects of Fertilisation and Organic Matter Removal on Mean FH Litter Microbial Biomass at the LTSP Sites

SAMPLING ROUND	TREATMENT	FH Litter Microbial Biomass ($mg\ NH_4\text{-}N$ / kg FH Litter) WOODHILL		TARAWERA		BERWICK		BURNHAM		KINLEITH		GOLDEN DOWNS	
SUMMER 2002	FERT	46.1	*8.67*	**a** 66.3	*3.99*	**a** 105.1	*6.67*	**a** 48.7	*4.66*	**a** 111.9	*10.90*	197.5	*12.59*
	NO FERT	50.1	*7.40*	**b** 100.1	*6.27*	**b** 193.2	*13.70*	**b** 83.0	*5.45*	**b** 76.5	*11.37*	171.0	*16.14*
	FF	64.7	*9.63*	83.8	*10.64*	NA		NA		97.9	*10.71*	172.3	*21.98*
	WT	46.5	*8.60*	90.5	*9.91*	144.8	*21.87*	61.8	*7.35*	101.7	*14.45*	196.8	*17.10*
	SO	33.1	*6.61*	75.2	*2.34*	153.5	*15.31*	69.8	*8.19*	83.0	*18.12*	186.7	*14.36*
WINTER 2002	FERT	121.5	*10.79*			**a** 79.2	*20.34*					62.5	*10.37*
	NO FERT	144.5	*4.89*			**b** 108.4	*23.79*					74.2	*8.44*
	FF	129.3	*11.59*			NA						84.7	*15.76*
	WT	127.2	*12.79*			95.8	*27.80*					51.8	*7.17*
	SO	142.5	*7.80*			91.7	*16.09*					68.6	*6.91*
SUMMER 2003	FERT	164.5	*10.04*	20.4	*4.60*	72.8	*14.16*	13.9	*5.13*	115.9	*5.10*	13.4	*2.39*
	NO FERT	197.7	*16.46*	21.6	*1.92*	163.3	*32.38*	35.7	*8.67*	131.9	*8.80*	17.5	*2.61*
	FF	158.4	*15.76*	17.6	*3.49*	NA		NA		117.3	*8.13*	13.2	*1.71*
	WT	191.4	*8.94*	20.8	*3.20*	143.5	*32.87*	24.5	*9.14*	135.5	*9.95*	17.1	*3.84*
	SO	193.5	*22.75*	24.7	*5.52*	92.6	*22.78*	25.2	*6.90*	118.8	*8.15*	16.1	*3.32*
WINTER 2003	FERT	**a** 82.4	*9.30*			139.1	*21.91*					**a** 133.6	*12.89*
	NO FERT	**b** 120.3	*9.32*			162.2	*14.44*					**b** 181.3	*14.92*
	FF	88.3	*9.54*			NA						147.8	*24.60*
	WT	102.1	*18.87*			155.2	*20.69*					175.5	*17.59*
	SO	113.5	*8.38*			146.1	*16.99*					149.1	*10.64*

NA indicates treatment was not applied at this site
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

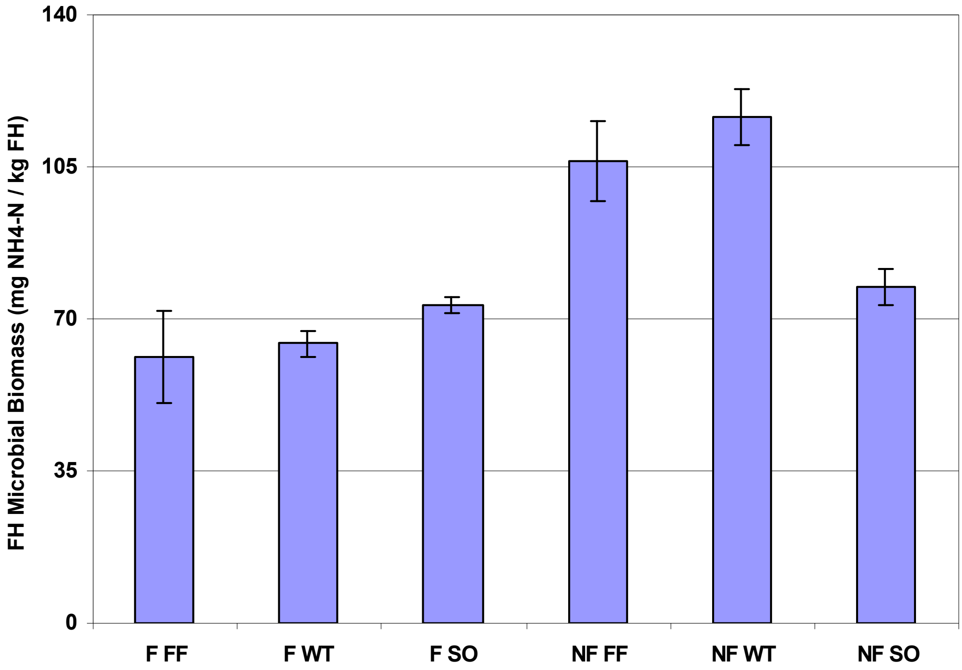
Woodhill FH Litter Microbial Biomass

The mean microbial biomass in the FH litter at Woodhill (Table 3.1) was decreased by fertilisation in all sampling rounds, although the extent of the decrease was statistically significant only in the winter 2003 sampling round (S. App. 2.1.4). The FH litter microbial biomass was not statistically affected by the organic matter removal treatments, although in the winter sampling rounds more FH litter microbial biomass was found in plots with less organic matter removal. In the summer sampling rounds, the response was variable. No significant interactions between the fertilisation and organic matter removal treatments at $\alpha = 0.05$ were found in the response of the FH litter microbial biomass at Woodhill (S. App. 2.1.1 – 2.1.4). The FH litter microbial biomass at Woodhill varied statistically with year of sampling (S. App. 2.1.5 and 2.1.6). FH litter microbial biomass values were significantly greater in summer 2003 than in summer 2002, and were significantly greater in winter 2002 than in winter 2003. FH litter microbial biomass did not vary significantly with season at Woodhill (S. App. 2.1.7).

Tarawera FH Litter Microbial Biomass

The mean FH litter microbial biomass was statistically lower in fertilised plots in the summer 2002 sampling round, but this effect was not significant in the analysis of the 2003 data (S. App. 2.2.1 and 2.2.2). There was no statistical difference in the response of the FH litter microbial biomass to the organic matter removal treatments in 2002 or 2003, and no consistent trend was evident. A significant treatment interaction was determined in the summer 2002 FH litter microbial biomass data (S. App. 2.2.1). As already noted, the mean FH litter microbial biomass was greater in the unfertilised plots in summer 2002, but further examination revealed that this decrease only occurred in the FF and WT treatment plots, and the FH litter microbial biomass in the unfertilised SO treatment plots was significantly lower than that in the unfertilised FF and WT plots. This is presented graphically in Figure 3.1.

Figure 3.1: Effects of Treatments on FH Litter Microbial Biomass at Tarawera in 2002



Error bars indicate the standard error of the mean

FH litter microbial biomass at Tarawera varied statistically with year of sampling at Tarawera, and was significantly greater in 2002 than in 2003 (S. App. 2.2.3).

Berwick FH Litter Microbial Biomass

Fertilisation decreased the FH litter microbial biomass in all four sampling rounds at Berwick (Table 3.1), but the differences were only statistical in the summer sampling rounds (S. App. 2.3.1 and 2.3.2). The response of the FH litter microbial biomass to the organic matter removal treatments varied considerably with sampling round, and no statistically significant results or trend were observed. No significant interactions at $\alpha = 0.05$ were found between the fertilisation and organic matter removal treatments in the FH litter microbial biomass data at Berwick. The FH litter microbial biomass at Berwick did not differ significantly between the 2002 and 2003 summer sampling rounds, but FH litter biomass values were significantly higher in winter 2003 than in winter 2002 (S. App. 2.3.6). Season of sampling did not statistically affect FH litter microbial biomass (S. App. 2.3.7).

Burnham FH Litter Microbial Biomass

Fertilisation substantially decreased the FH litter microbial biomass in both of the summer sampling rounds at Burnham (Table 3.1), but the decrease was significant only in 2002 (S. App. 2.4.1). The mean FH litter microbial biomass values in the WT plots were lower than that in the SO plots both 2002 and 2003, but the difference was not statistically significant in either year. No significant interactions between the fertilisation and organic matter removal treatments were calculated in the FH microbial biomass data at the Burnham site. Significantly more microbial biomass was found in the FH litter in 2002 than in 2003 (S. App. 2.4.3).

Kinleith FH Litter Microbial Biomass

The Kinleith FH litter microbial biomass values presented in Table 3.1 were statistically increased by fertilisation in 2002, but this effect was not observed in 2003, as the mean value was actually greater in the unfertilised plots, although not significantly (S. App. 2.5.2). The organic matter removal treatments did not statistically influence the FH litter microbial biomass in either year, although the greatest values were found in the WT plots in both years. No significant interactions were found between the fertilisation and organic matter removal treatments in the FH litter microbial biomass values. Year of sampling was found to have a significant effect, as the mean FH litter microbial biomass was significantly greater in 2002 (S. App. 2.5.3).

Golden Downs FH Litter Microbial Biomass

Fertilisation did not consistently affect FH litter microbial biomass at Golden Downs (Table 3.1), and the only statistically significant effect was a decrease in mean FH litter microbial biomass in the fertilised plots in the winter 2003 sampling (S. App. 2.6.4). The response of the FH litter microbial biomass to organic matter removal was also inconsistent, and no significant effects were detected at any time. No significant interactions between the fertilisation and organic matter removal treatments were calculated in any of the four sampling rounds (S. App. 2.6.1 – 2.6.4). The mean FH litter microbial biomass values varied significantly with year (S. App. 2.6.5 and

2.6.6), and FH litter microbial biomass was statistically greater in summer 2002 than in summer 2003, and greater in winter 2003 than winter 2002.

3.3.2: Response of Soil Microbial Biomass to Fertilisation and Organic Matter Removal Treatments at the Individual LTSP Sites

Table 3.2: Effects of Fertilisation and Organic Matter Removal on Mean Soil Microbial Biomass

SAMPLING ROUND	TREATMENT	Soil Microbial Biomass (mg NH_4-N / kg FH Litter)																	
		WOODHILL			TARAWERA			BERWICK			BURNHAM			KINLEITH			GOLDEN DOWNS		
SUMMER 2002	FERT		2.0	*0.27*		7.7	*0.81*		11.1	*0.95*	**a**	3.5	*0.43*	**a**	17.8	*1.61*		12.7	*1.40*
	NO FERT		1.9	*0.19*		9.5	*1.02*		16.1	*2.09*	**b**	5.2	*0.56*	**b**	12.1	*1.04*		15.1	*2.39*
	FF		2.3	*0.37*	**a**	5.7	*0.59*		NA			NA			11.8	*0.74*	**a**	9.2	*0.85*
	WT		2.0	*0.16*	**b**	9.7	*1.09*		13.0	*2.44*		4.0	*0.71*		17.2	*2.21*	**a b**	13.7	*1.31*
	SO		1.6	*0.19*	**b**	10.6	*0.92*		14.2	*0.86*		4.7	*0.38*		15.9	*1.96*	**b**	18.9	*3.07*
WINTER 2002	FERT		8.8	*0.92*					13.8	*0.89*								38.7	*4.18*
	NO FERT		12.9	*2.20*					16.3	*0.97*								51.2	*10.86*
	FF	**a**	6.8	*0.75*					NA								**a**	30.5	*2.67*
	WT	**a b**	11.1	*1.13*					14.4	*0.95*							**a b**	38.5	*6.21*
	SO	**b**	14.7	*2.82*					15.8	*1.04*							**b**	65.9	*13.69*
SUMMER 2003	FERT	**a**	10.4	*1.26*		37.7	*1.94*		13.2	*1.05*		4.4	*0.62*	**a**	47.6	*4.19*		11.4	*1.29*
	NO FERT	**b**	13.6	*1.61*		34.0	*2.05*		15.0	*1.94*		6.5	*0.96*	**b**	36.1	*2.93*		12.9	*2.13*
	FF	**a**	7.9	*1.35*	**a**	30.2	*1.75*		NA			NA		**a**	30.4	*3.12*	**a**	10.2	*1.12*
	WT	**a b**	11.9	*1.21*	**a b**	38.0	*2.31*		12.9	*1.13*		4.3	*0.56*	**b**	42.7	*4.12*	**a**	9.1	*1.42*
	SO	**b**	16.2	*1.27*	**b**	39.4	*2.15*		15.3	*1.85*		6.6	*0.96*	**b**	52.5	*3.74*	**b**	17.0	*2.52*
WINTER 2003	FERT		8.3	*1.24*				**a**	16.4	*1.80*								48.9	*4.17*
	NO FERT		11.6	*1.54*				**b**	23.6	*1.35*								62.2	*12.73*
	FF	**a**	6.3	*1.15*					NA									39.6	*4.70*
	WT	**a b**	10.2	*1.63*					18.4	*1.77*								49.7	*7.77*
	SO	**b**	13.5	*1.32*					21.6	*2.13*								77.4	*15.56*

NA indicates treatment was not applied at this site

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Woodhill Soil Microbial Biomass

The soil microbial biomass tended to be decreased by fertilisation at Woodhill, although this was not observed in summer 2002 (Table 3.2). The only statistical decrease in soil microbial biomass was in the summer 2003 sampling round (S. App. 2.1.2). Increasing levels of organic matter removal tended to decrease the soil microbial biomass proportionately, as the mean soil microbial biomass was significantly lower in the FF plots than in the SO plots in summer 2003 and in both winter sampling rounds (S. App. 2.1.2 – 2.1.5). This trend was reversed in summer 2002, as soil microbial biomass was greatest in FF plots and least in SO plots, but the differences were not statistical. No significant interactions at $\alpha = 0.05$ were found between the fertilisation and organic matter removal treatments in the Woodhill sampling rounds (S. App. 2.1.1 – 2.1.4). The soil microbial biomass varied with year in the summer sampling rounds, as microbial biomass was statistically greater in 2003, but soil biomass did not vary with year in the winter sampling rounds (S. App. 2.1.6). Soil microbial biomass was significantly higher in winter than in summer (S. App. 2.1.7).

Tarawera Soil Microbial Biomass

Soil microbial biomass was not statistically affected by fertilisation in either of the summer sampling rounds, and no trend was evident in the results (Table 3.2). The soil microbial biomass varied significantly with the level of the organic matter removal treatment, as mean values were statistically lower in the FF plots than that in the WT and SO plots in 2002, and mean values were significantly lower in the FF plots than in the SO plots in 2003 (S. App. 2.2.1 and 2.2.2). No statistical interactions between the fertilisation and organic matter removal treatments were calculated in either year. The year of sampling was found to significantly influence soil microbial biomass, as the mean values were greater in summer 2003 than in summer 2002 (S. App. 2.2.3)

Berwick Soil Microbial Biomass

The mean soil microbial biomass values tended to be decreased in the fertilised plots in all of the sampling rounds (Table 3.2), but the only statistical difference between the fertilised and unfertilised plots was in winter 2003 (S. App. 2.3.4). Similarly, the mean soil microbial biomass values were consistently lower in the WT plots than in the SO plots, but the magnitude of the decreases were not statistically significant in any of the sampling rounds (S. App. 2.3.1 – 2.3.4). No significant interactions were found between the fertilisation and organic matter removal treatments at Berwick. The soil microbial biomass values did not differ significantly between the two summer sampling rounds, but values were significantly higher in winter 2003 than in winter 2002 (S. App. 2.3.6). The season of sampling statistically affected soil microbial biomass at Berwick, as the mean values were significantly greater in the winter sampling rounds than in summer (S. App. 2.3.7).

Burnham Soil Microbial Biomass

Soil microbial biomass at Burnham was decreased by fertilisation in 2002 and 2003, but the decrease was statistical significant only in 2002 (Table 3.2). The decrease in 2003 was very close to significance (Pr (F) value of 0.073), but this was above the threshold of 0.05. The mean soil microbial biomass values tended to be greater in the SO plots than in the WT plots, but the differences were not significant in either year, although the Pr (F) value in 2003 was 0.052, extremely close to the 0.05 threshold (S. App. 2.4.2). No significant interactions between the fertilisation and organic matter removal treatments were calculated in the Burnham soil microbial biomass data. The mean soil microbial biomass values did not vary statistically with year.

Kinleith Soil Microbial Biomass

The soil microbial biomass values for Kinleith reported in Table 3.2 were statistically increased by fertilisation in both sampling rounds (S. App. 2.5.1 and 2.5.2). The organic matter removal treatment also influenced soil microbial biomass at Kinleith, as the mean values were lowest in the FF treatment plots, and the numerical difference was statistically significant in the summer 2003 sampling round (S. App. 2.5.2). No significant interactions between the fertilisation and organic matter removal treatments were detected in the soil microbial biomass data. A significant year effect was identified, as the mean soil microbial biomass values were statistically greater in 2003.

Golden Downs Soil Microbial Biomass

The mean soil microbial biomass values reported in Table 3.2 were uniformly lower in fertilised plots in all four sampling rounds at Golden Downs, but the decreases were not significant in any of the sampling rounds (S. App. 2.6.1 – 2.6.4). The organic matter removal treatment strongly influenced soil microbial biomass, as the mean values were greatest in the SO treatment plots in all sampling rounds. Statistical differences between the levels of the organic matter removal treatment were calculated for all of the sampling rounds with the exception of winter 2003, but this was also close to significance as the Pr (F) value was 0.056 (S. App. 2.6.4). No statistical interactions between the fertilisation and organic matter removal treatments were found in the analysis of the Golden Downs soil microbial biomass data. Soil microbial biomass did not vary statistically with the year of sampling, (S. App. 2.6.5 – 2.6.6), but did vary with season, as soil microbial biomass was significantly higher in winter than in summer in both years (S. App. 2.5.7).

3.3.3: Effects of the Treatments on Microbial Biomass at all Sites

Table 3.3: Effects of Fertilisation and Organic Matter Removal on Mean FH Litter and Soil Microbial Biomass at all Sites

	TREATMENT	ALL SITES									WOODHILL / TARAWERA / KINLEITH / GOLDEN DOWNS								
		SUMMER 2002			SUMMER 2003			COMBINED SUMMERS			SUMMER 2002			SUMMER 2003			COMBINED SUMMERS	
		(mg NH_4-N kg^{-1} FH litter or soil)									(mg NH_4-N kg^{-1} FH litter or soil)								
FH LITTER	FERT	101.3	*7.93*	**A**	65.1	*7.82*	**a**	83.2	*5.81*									
	NO FERT	112.0	*7.91*	**B**	88.9	*10.59*	**b**	100.5	*6.69*									
	FF	NA			NA			NA			107.4	*10.47*		71.2	*11.87*		89.3	*8.25*
	WT	109.7	*9.51*		84.3	*11.91*		97.0	*7.74*		113.0	*11.96*		84.5	*13.70*		98.8	*9.28*
	SO	103.1	*9.21*		73.5	*10.46*		88.3	*7.14*		98.6	*12.03*		81.3	*13.82*		89.9	*9.23*
SOIL	FERT	9.7	*0.84*		22.6	*2.34*		16.2	*1.37*									
	NO FERT	10.3	*0.88*		21.1	*1.74*		15.7	*1.09*									
	FF	NA			NA			NA		**a**	7.6	*0.72*	**a**	20.3	*2.21*	**a**	13.9	*1.42*
	WT	10.3	*1.02*	**A**	20.1	*2.41*	**a**	15.2	*1.40*	**b**	11.2	*1.23*	**b**	26.2	*3.09*	**b**	18.7	*1.93*
	SO	11.4	*1.10*	**B**	24.7	*2.61*	**b**	18.0	*1.58*	**b**	12.4	*1.52*	**c**	32.0	*3.21*	**c**	22.2	*2.18*

NA indicates treatment was not applied at this site
Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Effects of Fertilisation

The FH litter microbial biomass values for all sites in Table 3.3 tended to be decreased by the application of fertiliser, although the magnitude of the decrease was not statistically significant in summer 2002 (S. App. 2.7.1). Soil microbial biomass was not significantly affected by the fertilisation regimes in either year, or when the data from both years was combined.

Effects of Organic Matter Removal

The combined mean FH litter microbial biomass values for all sites tended to be greater in the WT plots than in the SO plots (Table 3.3), but this difference was not statistically significant at any time (S. App. 2.8.1 – 2.8.3). Conversely, the mean soil microbial biomass was lower in the WT plots in both summer sampling rounds, and the decrease was significant in summer 2003, and when the data from both summer sampling rounds was combined. When only the four sites with all three of the organic matter removal treatments were considered, the mean FH litter microbial biomass was statistically unaffected, but the mean soil microbial biomass was found to decrease significantly with increasing levels of organic matter removal in 2002, 2003 and when the data from both years was combined (S. App. 2.9.1 – 2.9.3).

Significant Site: Fertilisation Interactions

The FH litter and soil microbial biomass values were found to vary significantly with site, and the response to fertilisation at the six sites was also found to vary significantly with site in the summer sampling rounds (S. App. (S. App. 2.7.1 – 2.7.3). Fertilisation strongly decreased microbial biomass estimates at Berwick and Burnham, and decreased microbial biomass to a lesser extent at Woodhill, Tarawera and Golden Downs. The opposite response at Kinleith was observed, as fertilisation statistically increased FH litter and soil microbial biomass in three cases.

Significant Site: Organic Matter Removal Interactions

Across the six LTSP sites, the response of the FH litter and soil microbial biomass to the WT and SO organic matter removal treatments did not vary statistically with site, but the response to all three organic matter removal treatments did vary significantly with site in summer 2003 (S. App. 2.9.3).

3.3.4: FH Litter Microbial Biomass Linear Regression Results

Table 3.4: Relationships between Site Physical and Chemical Parameters and FH litter Microbial Biomass

SITE	FH litter Microbial Biomass				
	R^2	p Value	Parameters	Coefficients	Intercept
WOODHILL					
SUMMER 2002	0.35	0.040	Soil pH Soil C/N	56.85 -1.16	-194.8
WINTER 2002	0.34	0.011	FH Mass	-10.35	162.3
SUMMER 2003			No Relationship		
WINTER 2003	0.33	0.013	FH Mass	-11.71	136.4
TARAWERA					
SUMMER 2002	0.50	0.001	FH C/N FH Mass C	3.60 -21.58	-9.7
SUMMER 2003	0.25	0.046	FH Moisture Soil Moisture	97.64 154.28	-15.3
BERWICK					
SUMMER 2002	0.34	0.017	FH C/N	2.77	26.5
WINTER 2002			No Relationship		
SUMMER 2003	0.40	0.008	FH Mass N	-3322.10	243.1
WINTER 2003			No Relationship		
BURNHAM					
SUMMER 2002	0.52	0.002	Soil pH	63.83	-216.0
SUMMER 2003			No Relationship		
KINLEITH					
SUMMER 2002	0.36	0.009	Soil pH Soil C/N	79.63 -6.88	-145.7
SUMMER 2003			No Relationship		
GOLDEN DOWNS					
SUMMER 2002	0.33	0.016	FH Moisture FH C/N	345.82 -1.97	130.1
WINTER 2002	0.26	0.010	FH Moisture	530.52	-305.3
SUMMER 2003			No Relationship		
WINTER 2003	0.18	0.041	FH Moisture	958.56	-504.1

FH litter microbial biomass was statistically correlated to the physical and chemical parameters at all of the LTSP sites in the majority of the sampling rounds (Table 3.4), but in general the degree of variation explained by the models using these parameters was not high (R^2 = 0.18 – 0.52). The parameters used in the models varied considerably from site to site, and also between sampling rounds at the same sites, although the different number of parameters measured in the summer 2002, summer 2003 and winter sampling rounds explained some of the latter variation.

At Woodhill, Burnham and Kinleith in summer 2002 soil pH was positively correlated to FH litter microbial biomass, and soil carbon: nitrogen ratios were also important at Woodhill and Kinleith, although as these parameters were not measured in any other sampling round, they do not feature the summer 2003 regression models at these sites, which were not statistically significant. At Tarawera and Berwick in both summer sampling rounds, and at Golden Downs in summer 2002, statistically significant regression models were calculated using various parameters of the FH litter and soil moisture, although the parameters were not consistent across the sites, or from year to year.

In the winter sampling rounds, FH litter mass was statistically negatively correlated with FH litter microbial biomass at Woodhill in both 2002 and 2003, and FH litter moisture levels were positively correlated to FH litter microbial biomass at Golden Downs in both winter sampling rounds. No statistically significant regression models were calculated at Berwick in either winter sampling round.

3.3.5: Soil Microbial Biomass Linear Regression Results

Table 3.5: Relationships between Site Physical and Chemical Parameters and Soil Microbial Biomass

SITE	R^2	p Value	Soil Microbial Biomass Parameters	Coefficients	Intercept
WOODHILL					
SUMMER 2002	0.30	0.069	Soil C/N FH Mass N	-0.04 -6.06	3.8
WINTER 2002	0.69	0.000	Soil Moisture	49.67	0.6
SUMMER 2003	0.29	0.021	Soil Moisture	29.48	3.9
WINTER 2003			No Relationship		
TARAWERA					
SUMMER 2002	0.68	0.000	Soil Moisture	67.03	-9.9
SUMMER 2003			No Relationship		
BERWICK					
SUMMER 2002	0.33	0.021	FH C/N	0.26	2.0
WINTER 2002	0.46	0.017	FH Moisture FH Mass	-62.37 -0.91	60.9
SUMMER 2003			No Relationship		
WINTER 2003			No Relationship		
BURNHAM					
SUMMER 2002	0.79	0.000	Soil Moisture Soil pH	70.14 5.02	-32.2
SUMMER 2003			No Relationship		
KINLEITH					
SUMMER 2002	0.56	0.000	Soil % N FH Density	26.25 -0.07	8.5
SUMMER 2003	0.80	0.000	Soil Moisture FH Mass N	158.66 438.06	-22.5
GOLDEN DOWNS					
SUMMER 2002	0.84	0.000	Soil Moisture	117.40	-11.1
WINTER 2002	0.91	0.000	Soil Moisture	264.99	-51.4
SUMMER 2003	0.44	0.000	Soil Moisture	155.42	-1.6
WINTER 2003	0.85	0.000	Soil Moisture	292.73	-37.9

The statistical relationships between soil microbial biomass and the physical and chemical parameters described in Table 3.5 were generally stronger than that observed with the FH litter microbial biomass, and the degree of variation explained by the soil microbial biomass regression models was also higher ($R^2 = 0.29 – 0.91$). Soil moisture was the most common and most important parameter in the regression models, and was positively correlated to soil biomass at least once at every site, although the models were not always statistically significant. The other physical and chemical parameters were occasionally important in some sampling rounds, but no other parameter was as consistently correlated to soil microbial biomass.

Soil moisture was statistically positively correlated to soil microbial biomass at Tarawera, Burnham and Golden Downs in summer 2002, and at Woodhill, Kinleith and Golden Downs in summer 2003. Of the other parameters, the FH litter carbon: nitrogen ratio was positively correlated to soil microbial biomass at Berwick in summer 2002, and the percentage of nitrogen in the soil was positively correlated to soil microbial biomass in summer 2002, but neither of these parameters were important in the summer 2003 sampling rounds.

In the winter sampling rounds, soil moisture was positively correlated to soil microbial biomass at Woodhill and Golden Downs in 2002 and 2003, although the regression was not significant at Woodhill in 2003. At Berwick, FH litter moisture and mass were negatively correlated to soil microbial biomass in 2002, but not in 2003.

3.3.6: FH litter Microbial Biomass Linear Regression Results at all Sites

Table 3.6: Relationships between Site Physical and Chemical Parameters and FH Litter Microbial Biomass at all Sites Combined

SAMPLING ROUND	R^2	p Value	FH litter Microbial Biomass			
			Parameters	Individual r^2	Coefficients	Intercept
SUMMER 2002	0.54	0.000	Soil pH FH Density Soil % C FH C/N	0.17 0.14 0.13 0.10	42.40 -0.36 3.73 1.42	-145.3
WINTER 2002	0.25	0.001	FH Density FH Mass FH Moisture	0.15 0.8 0.02	0.98 -18.73 393.21	-206.0
SUMMER 2003	0.69	0.000	FH Moisture FH Mass	0.64 0.05	336.85 -12.78	-24.6
WINTER 2003	0.20	0.002	FH Mass FH Density	0.12 0.08	-15.55 -0.53	246.1

Across the six sites, the regression models for the summer sampling round data explained a greater degree of variation in FH litter microbial biomass than the models for the winter sampling rounds. The degree of variation explained by the summer 2003 model was found to be greater than the summer 2002 model, even though the summer 2003 model was generated using a smaller number of parameters. When the winter data from Woodhill, Berwick and Golden Downs was combined, FH litter mass was calculated to be negatively correlated with FH litter microbial biomass in both winter sampling rounds. FH litter density was also statistically correlated to FH litter microbial biomass in both years, but the nature of the correlation varied with year.

3.3.7: Soil Microbial Biomass Linear Regression Results at all Sites

Table 3.7: Relationships between Site Physical and Chemical Parameters and Soil Microbial Biomass at all Sites Combined

SAMPLING ROUND	Soil Microbial Biomass					
	R^2	p Value	Parameters	Individual r^2	Coefficients	Intercept
SUMMER 2002	0.73	0.000	Soil % C	0.38	0.67	-4.5
			Soil Moisture	0.31	21.52	
			FH C/N	0.04	0.09	
WINTER 2002	0.50	0.000	Soil Moisture	0.42	128.27	-5.2
			FH Density	0.08	-0.19	
SUMMER 2003	0.30	0.000	FH C/N	0.09	-0.77	71.2
			FH Density	0.09	0.08	
			Soil Moisture	0.07	54.04	
			FH % N	0.03	-25.65	
			FH Moisture	0.02	-18.02	
WINTER 2003	0.71	0.000	Soil Moisture	0.71	258.57	-35.2

Across the data set from the summer sampling rounds at the six sites, soil microbial biomass was modelled more accurately by the physical and chemical parameters in 2002 than in 2003. Soil moisture was positively related to soil microbial biomass in both years, and the carbon: nitrogen ratio of the FH litter was also significant to the accuracy of the models, although the polarity of the relation varied with year of sampling. In the winter sampling rounds, the soil moisture parameters was the most important factor in the regression models, and was positively correlated to soil microbial biomass in winter 2002 and 2003.

3.3.8: Nitrogen Mineralisation Rates and Relationship with Biomass

Nitrogen mineralisation after ten days incubation was not statistically influenced by fertilisation at any of the sites (Table 3.8), although the decrease in the mineralisation rate in response to fertilisation in the Woodhill soil samples was close to statistical significance (Pr (F) = 0.063). Significant differences were found between the levels of the organic matter removal treatments at Woodhill and Berwick, as increasing levels of organic matter removal tended to decrease the rate of nitrogen mineralisation by the microbial community. This trend was also observed in the mean nitrogen mineralisation rates in the Golden Downs soil samples, but the high level of variation in the mineralisation rates prevented the differences from being significant at $\alpha = 0.05$ (Refer S. App. 2.10).

Table 3.8: Effects of Fertilisation and Organic Matter Removal on Soil Nitrogen Mineralisation Rates in Winter 2003

SITE	TREATMENT		Nitrogen Mineralisation (mg NH_4-N / kg soil)	
WOODHILL	FERT		58.9	*9.47*
	NO FERT		74.6	*9.20*
	FF	**a**	34.1	*3.59*
	WT	**b**	72.8	*7.88*
	SO	**b**	93.3	*6.83*
BERWICK	FERT		240.6	*8.37*
	NO FERT		220.1	*1.35*
	WT	**a**	210.0	*8.13*
	SO	**b**	250.7	*14.60*
GOLDEN DOWNS	FERT		475.5	*42.77*
	NO FERT		518.4	*70.80*
	FF		401.2	*49.44*
	WT		466.6	*75.04*
	SO		623.0	*65.16*

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

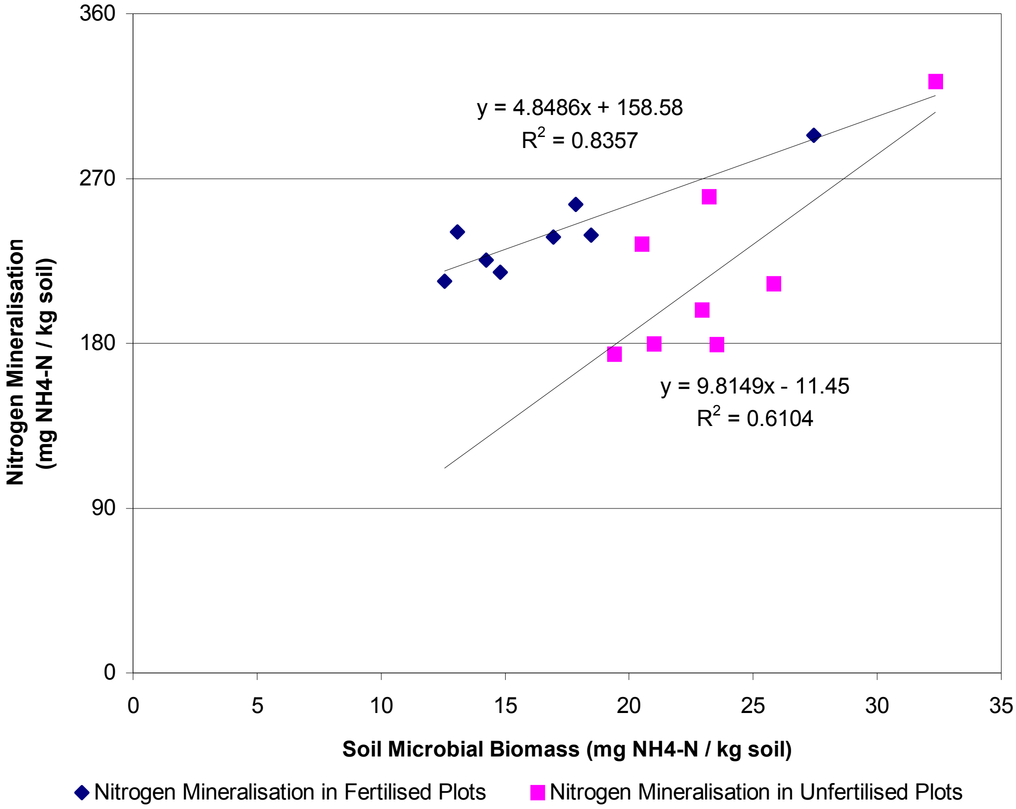
Table 3.9: Relationships between Nitrogen Mineralisation Rates and Soil Microbial Biomass in Winter 2003

SITE	TREATMENT	r^2	p Value	Coefficient	Intercept
WOODHILL	ALL	0.47	0.002	4.41	22.7
	FERT	0.50	0.033	5.39	14.0
	NO FERT	0.38	0.079	3.68	31.8
BERWICK	ALL	0.17	0.115	3.01	169.4
	FERT	0.84	0.002	4.85	158.6
	NO FERT	0.61	0.022	9.82	-11.5
GOLDEN DOWNS	ALL	0.79	0.000	5.40	197.2
	FERT	0.85	0.000	9.47	12.1
	NO FERT	0.83	0.000	5.06	204.0

Note: Treatment types were as follows:
ALL: The regression included all plots
FERT: The regression included only the fertilised plots
NO FERT: The regression included only the unfertilised plots

The r^2 values and coefficients presented in Table 3.9 indicated that the rate of nitrogen mineralisation in the incubated soil samples was consistently positively correlated with soil microbial biomass. The data was also separated based on the fertilisation treatment, as examination of graphic representations of the data indicated that the effects of the fertilisation treatment may have been obfuscating detection of the relationship between soil microbial biomass and nitrogen mineralisation. This was found to be the case at Berwick, as two separate regressions equations were found to explain a much greater degree of variation in the relationship for the fertilised and unfertilised plots separately (refer Figure 3.2), and this approach also slightly improved the r^2 values at Golden Downs, but did not improve the accuracy of the regression model for the Woodhill data. Separation of the data based on the organic matter removal treatments did not substantially improve the r^2 values in any case.

Figure 3.2: Effect of Fertilisation on the Relationship between Soil Microbial Biomass and Nitrogen Mineralisation at Berwick



3.4: DISCUSSION

The chloroform fumigation – extraction technique used in this study has been the subject of criticism regarding the time and labour required to accurately perform the method, and the reproducibility of the results that are produced (Beck *et al*., 1997; Turner *et al*., 2001). The first concern was not regarded as an issue in this study, but it was concluded that assessing the reproducibility of the fumigation – extraction technique was important. Consequently, a trial was carried out to assess the internal variability in the method, the details of which are presented in Appendix Four. Statistical analysis of the results of the trial determined that any variation in the values produced by the fumigation – extraction technique were not significant, and consequently the technique could be used with confidence in this study. Furthermore, the chloroform fumigation – extraction technique is still widely employed, and it has also been shown that there is a strong relationship between estimates of microbial biomass using this method and those produced by newer methods, such as phospholipid fatty acid extraction (Bailey *et al*., 2002; Leckie *et al*., 2004).

As in the previous chapter, the variation in FH litter and soil microbial biomass across site, year and time will not be considered in great detail, as the focus of this chapter is to identify and discuss the effects and interactions of the fertilisation and organic matter removal treatments on microbial biomass, as well the relationships between microbial biomass and the physical and chemical parameters measured Chapter Two.

3.4.1: Spatial and Temporal Variations in FH Litter and Soil Microbial Biomass

Site Variations

Both FH litter and soil microbial biomass estimates varied significantly with site in summer 2002 and 2003 (refer S. App. 2.7, 2.8 and 2.9). Previous studies have found that a range of site characteristics such as soil properties and climatic conditions can substantially influence soil microbial biomass (Wardle, 1992), and as a number of soil and climatic characteristics were found to vary between the six LTSP sites (refer Tables 1.1 and 1.2; Appendix

One) this site-based variation in the soil microbial biomass data was anticipated. The variation in the FH litter microbial biomass was similarly considered to be the result of differences in the environment at the site, but no previous studies were available to support this assertion.

Annual Variations

FH litter microbial biomass varied statistically with year in the summer sampling rounds at all of the six LTSP sites with the exception of Berwick, and in the winter sampling rounds FH litter microbial biomass varied with year at all three measured sites (S. App. 2.1 – 2.6). Significant variation with year was also calculated for the soil microbial biomass data, but only at Woodhill, Tarawera and Kinleith in summer, and at Berwick in the winter sampling rounds. Some of this variation in microbial biomass was related to the differences in available moisture in 2002 and 2003, and will be discussed in greater detail in section 3.4.4. Statistically significant annual variations in measurements of litter layer and soil microbial biomass have been reported previously, and have similarly been explained by differences in precipitation and other climatic factors from year to year (Bååth and Söderström, 1982; Bohlen *et al*., 2001).

Seasonal Variations

At Woodhill, Golden Downs and Berwick, FH litter microbial biomass did not vary statistically with season (S. App. 2.1.7, 2.3.7 and 2.6.7), but mean soil microbial biomass increased significantly in winter at all three sites, and the magnitude of the increase was considerable at Golden Downs in particular (Table 3.2). In a review of the influence of macroclimatic and soil conditions on temporal variability in soil microbial biomass, Wardle (1998a) reported that soil microbial biomass carbon values tended to increase in summer/spring and decrease in winter, citing temperature as the dominant factor at higher latitudes in particular. However this trend was only generally observed, and in several cases maximum biomass values were actually found to occur in winter (Wardle, 1998a), so the seasonal variations in soil microbial biomass at the three LTSP sites were not totally anomalous.

3.4.2: Effects of Fertilisation and Organic Matter Removal Treatments on FH Litter and Soil Microbial Biomass

FH Litter Microbial Biomass

Fertilisation was found to substantially influence FH litter microbial biomass. Across the six LTSP sites, the mean FH litter microbial biomass estimates were lower in the fertilised plots in the summer sampling rounds, although the difference was not statistically significant in 2002 (Table 3.3). This trend was consistently observed at all of the individual sites, with the exception of Kinleith, where the FH litter microbial biomass was statistically greater in fertilised plots in the summer 2002 sampling round (Table 3.1). Ohtonen *et al*. (1992), using chloroform fumigation-extraction to study the effects of management on microbial communities in forest plantations, found that microbial biomass carbon was significantly decreased in plots that had received annual fertilisation for five years, and microbial biomass nitrogen were also decreased by fertilisation, although the differences were not statistically significant. The results of Ohtonen *et al*. (1992) tend to agree with those of this study, but as the period of fertilisation was less than at any of the LTSP study sites, some variation in response was expected. It has been suggested that the decrease in microbial biomass associated with fertilisation may be the result of nitrate accumulation, which negatively influences microbial populations, and has the potential to decrease microbial biomass (Söderström *et al*., 1983). It was unclear why fertilisation increased FH litter microbial biomass at Kinleith, and no reasons for this can be given at this time.

The organic matter removal treatments did not statistically influence the FH litter microbial biomass at any of the LTSP sites individually, or the mean values across the sites (Tables 3.1 and 3.3), and no trends were evident in the response to increasing levels of organic matter removal. This result was in agreement with that of Ohtonen *et al*. (1992), who found that the removal of harvest debris and the forest floor litter layer prior to the establishment of the next rotation of trees did not significantly influence the FH litter microbial biomass five years after the treatment was applied.

Soil Microbial Biomass

At the individual sites, fertilisation tended to decrease soil microbial biomass, but statistically significant decreases occurred only twice, and at the Kinleith site, significantly more soil microbial biomass was found in the fertilised plots in both 2002 and 2003 (Table 3.2). The mean soil microbial biomass values across all of the LTSP sites did not show a consistent trend in response to fertilisation (Table 3.3), which was due to the strong influence of the increases in biomass at the Kinleith site, as these drove up the mean values in the fertilised plots. A number of other studies investigating the effects of mineral fertiliser application in plantation forests have reported significant decreases in soil microbial biomass in response to additions of nitrogen (Ohtonen *et al*., 1992; Blazier *et al*., 2003; Lee and Jose, 2003, Wallenstein *et al*., 2006), and phosphorous applications have also been found to decrease estimates of fungal biomass (Pampoline *et al*., 2002). In the case of nitrogen addition, the accumulation of nitrates has been proposed to be the mechanism responsible for the decrease in soil microbial biomass (Söderström *et al*., 1983; Blazier *et al*., 2003), and the potential for increased nitrogen availability to increase rates of carbon mineralisation, and therefore decrease the mass of organic carbon in the soil, has also been linked to decreased soil microbial biomass (Lee and Jose, 2003). However, as the soil microbial biomass was neither statistically or consistently decreased by fertilisation at the LTSP sites, and was in fact significantly increased at the Kinleith site, it was concluded that these processes were either not occurring or not substantially influencing soil microbial biomass at the LTSP sites. The mechanism for the increase in soil microbial biomass in response to fertilisation at Kinleith was unknown. It has been reported that short-term increases in soil microbial biomass may occur as nitrogen limitations are reduced immediately after fertilisation (Gallardo and Schlesinger, 1994; Lee and Jose 2003), but as the last fertiliser application at Kinleith occurred over three years prior to the summer 2002 sampling round, this does not adequately explain the increases at Kinleith.

The organic matter removal treatments strongly influenced the soil microbial biomass, as biomass values tended to decrease proportionally with increasing levels of organic matter removal at the six LTSP sites, and at this point it is important to reiterate that the effects of the organic matter removal treatments have persisted at the LTSP sites without any reinforcement for up to 17 years after establishment. At the individual sites, statistically significant decreases in soil microbial biomass were calculated in the FF treatment plots in many cases, and the biomass values in the WT plots tended to be lower than that in the SO treatment plots as well (Table 3.2), although the differences were not statistically significant as often. Across all sites, the mean soil microbial biomass was statistically lower in the WT plots than in the SO plots, and when the data from only the four sites with all three organic matter removal treatments was analysed, the biomass values were statistically lowest in the FF treatment plots in 2002, and in 2003 all three treatment plots were statistically distinct (Table 3.3). Previous studies in plantation forests have tended to suggest that post-harvest organic matter removal treatments may influence the soil microbial biomass during the next rotation by reducing the quantities of available carbon and nitrogen in the soil, but statistically significant effects do not occur often. Bååth (1980) reported that the retention or removal of slash following clear cutting did not significantly influence estimates of soil fungal biomass, and Ohtonen *et al*. (1992) concluded that soil microbial biomass did not differ statistically between WT and SO treatment plots after five years, although the mass of nitrogen extracted from soil microbial tissue in the WT treatment plots tended to be lower. Another comparison of WT and SO treatments reported similar findings, concluding that there was no difference in soil microbial biomass between the two levels of organic matter removal, based on phospholipid fatty acid profiles in two second rotation forests (Bengtsson *et al*., 1998). One significant result was reported by Li *et al*. (2004), who found that microbial biomass nitrogen, as determined by chloroform fumigation-extraction, was significantly lower in FF plots than in SO treatment plots, although no statistical difference was calculated between the two levels of organic matter removal for microbial biomass carbon. Compared to this earlier research, the results of this study indicated that the organic matter removal treatments had a substantially stronger effect on soil microbial biomass at the LTSP sites than that described at other locations. Some of this variation in response may be explained by the length of time between site establishment and sampling, which was longer at the LTSP sites, but no definitive reason can be provided at this time.

3.4.3: Significant Fertilisation: Organic Matter Removal Treatment Interactions

A small number of statistically significant fertilisation: organic matter removal interaction terms were calculated for FH litter and soil microbial biomass at the individual LTSP sites, but no significant interactions were found when the site data was combined (S. App. 2.8 – 2.9). Consequently, the significant interaction terms were all considered to be aberrations rather than indicators of wider trends, as none of the interactions effects were observed consistently across the sites.

3.4.4: Relationship between Physical and Chemical Parameters and Microbial Biomass

Comparisons between the regression models for each of the sampling rounds at the LTSP sites was complicated by the variation in the physical and chemical parameters measured in each sampling round. All thirteen parameters were measured in the summer 2002 sampling round, but in the summer 2003 sampling round soil pH, soil carbon and nitrogen content, and the soil carbon nitrogen ratio were not measured. In the winter sampling rounds, the only parameters measured were FH litter mass, FH litter density and the moisture content of the FH litter and soil.

FH Litter Microbial Biomass

Comparisons of the regression models at the individual LTSP sites revealed that no single parameter of the physical and chemical environment had a strong relationship with FH litter microbial biomass at all six of the sites (Table 3.4), and the parameters that were statistically related to FH litter microbial biomass varied with site and time, although it must be reiterated that some parameters were not common to all sampling rounds.

Of the summer sampling rounds, statistically significant regression models were calculated for all of the sites in 2002, but only at two sites in 2003, and the summer 2002 regression models also tended to explain a greater degree of variation in FH litter microbial biomass values. This may have been a consequence of the exclusion of the soil chemistry parameters in the 2003 sampling rounds, such as soil pH, which was positively correlated with FH litter microbial biomass at Woodhill, Burnham and Kinleith in summer 2002, and the soil carbon: nitrogen ratio, which was negatively correlated to FH litter microbial biomass at Woodhill and Kinleith. Several parameters of the FH litter were statistically related to FH litter microbial biomass in isolated cases, but no single parameter of the FH litter was found to be of particular importance to the summer regression models. Soil pH has been reported to influence soil microbial biomass in a number of cases, with lower biomass values consistently found in more acidic soils (Wardle; 1992; Blagodatskaya and Anderson, 1998), and the results of this study indicate that the pH of the soil may also be affecting the microbial biomass in the FH litter above the soil surface.

In the winter sampling rounds, FH litter mass was negatively correlated to FH litter microbial biomass at Woodhill in both years, and FH litter moisture content was positively correlated to FH litter microbial biomass at Golden Downs in both years. None of the parameters were statistically related to FH litter microbial biomass at Berwick in either year (Table 3.4). The relationship between FH litter moisture and FH litter microbial biomass at Golden Downs agrees with the results of previous investigations into microbial characteristics in forest litter, which have reported that microbial biomass tends to be significantly decreased in drier conditions (Dilly *et al.*, 2001; Salamanca *et al.*, 2002). The reason for the negative relationship between FH litter mass and microbial biomass at Woodhill in the winter sampling rounds was not evident, as there was no consistent correlation between FH litter mass and moisture content at Woodhill in winter (Appendix Three), and consequently the mechanism responsible for this effect was unknown.

The FH litter microbial biomass regression models for the combined site data were significant in all four sampling rounds (Table 3.6). The parameter that was most strongly related to FH litter microbial biomass in summer 2002 was soil pH, and FH litter density, the percentage of carbon in the soil and the carbon: nitrogen ratio of the FH litter were also important to the regression model. FH litter moisture, density and mass were the only parameters included in the regression models for the three other sampling rounds. The degree of variation explained by the two winter regression models was less than that of the summer models, but it was interesting to note that the variation explained by the summer 2003 model was greater than that of the summer 2002 model, meaning that the reduction in available parameters did not reduce the predictive capacity across all sites, although this was the case at the majority of the individual sites (Table 3.4). It was speculated that the increase in the degree of variation explained by the summer 2003 model was caused by the increased importance of the FH litter moisture parameter, as the decreased rainfall levels in 2003 (Appendix One) may have made FH litter moisture content the most limiting factor to FH litter microbial biomass (Dilly *et al*., 2001; Salamanca *et al*., 2002).

Soil Microbial Biomass

At the individual LTSP sites it was evident that soil moisture content was the parameter most closely related to soil microbial biomass, as it was statistically important to the regression models at least once at five of the sites, and was positively related to soil microbial biomass in all cases (Table 3.5). Few other parameters of the soil or FH litter environment were found to influence soil microbial biomass, and none were consistent across year or season, although the variation in the measured parameters between sampling rounds may have been responsible for this.

Statistically significant regression models for soil microbial biomass were calculated for the summer 2002 sampling round at all sites with the exception Woodhill, and in summer 2003 significant regression models were calculated from the Woodhill, Kinleith and Golden Downs data (Table 3.5). The most influential physical and chemical parameter was soil moisture content, which has previously been reported to substantially affect soil microbial biomass (Bååth and Söderström, 1982; Bohlen *et al*., 2001). Other soil parameters have also been reported to significantly influence soil microbial biomass, such as soil carbon and nitrogen content, soil carbon: nitrogen ratios and the pH of the soil (Wardle, 1992; Blagodatskaya and Anderson, 1998; Peacock *et al*., 2001; Li *et al*., 2004), and these parameters were all measured in the summer 2002 sampling round. However, none of these factors featured regularly in the regression models calculated from the summer 2002 data, as soil pH was significantly related to microbial biomass only at Burnham, and soil nitrogen content was found to be significant only at Kinleith.

As with the summer sampling rounds, soil moisture was the most important parameter in the winter soil microbial biomass regression models at Woodhill and Golden Downs (Table 3.5), and this agreed with the findings of earlier studies (Bååth and Söderström, 1982; Bohlen *et al.*, 2001). At Berwick, FH litter moisture and mass were both statistically negatively correlated to soil microbial biomass, and no parameters were significantly related in 2003. Soil moisture was not statistically related to soil microbial biomass at Berwick in any of the four sampling rounds in summer and winter (Table 3.5), despite the fact that the climatic conditions affecting moisture levels at Berwick were not markedly different to those at other sites where soil moisture was found to influence soil microbial biomass (refer Appendix One and Two). Consequently, it was suggested that soil microbial biomass at Berwick was influenced by parameters of the FH litter and factors not measured in this study.

As expected from the regression models at the individual sites, the soil moisture parameter was calculated to be statistically important to all of the regression models from the combined sites data, and was positively related to soil microbial biomass in all cases (Table 3.7). The soil carbon content was also significantly related to soil microbial biomass in summer 2002, and despite not being significant in any of the regression models at the individual sites in summer 2002 (Table 3.5), was calculated to be more influential to soil microbial biomass in summer 2002 than soil moisture. This finding suggested that soil carbon levels were important to soil microbial biomass across the sites, as has been reported previously (Wardle, 1992; Li *et al.*, 2004), but variations in other parameters may impact more upon soil microbial biomass at any given site. However, this cannot be conclusively proven by the results of this study, as soil carbon content was not measured in the other sampling rounds. The degree of variation in soil microbial biomass explained by the summer 2003 regression model was substantially less than that explained by the summer 2002 model (r^2 values of 0.30 and 0.73 respectively), and this may have been caused by the lack of the soil carbon content parameter.

In the combined sites winter regression models, soil moisture was either the most important or only parameter related to soil microbial biomass (Table 3.7). The degree of variation in soil microbial biomass explained by the winter regression models was considerable, and indicated that the influence of soil moisture on soil microbial biomass was greater in winter than in summer, especially when it was taken into account that there were fewer physical and chemical parameters available to the winter regression models. It was not evident why soil moisture was more important to the regression models in the winter sampling rounds, as the rainfall levels at Woodhill, Berwick and Golden Downs did not differ substantially with season (Appendix One) and the temperature decreases in winter should have reduced rates of evaporation (Appendix Two), theoretically making it less likely that moisture would be limiting to microbial growth, and consequently no explanation for this seasonal change in the influence of the soil moisture parameter can be provided.

3.4.5: Variations in Rates of Nitrogen Mineralisation and Relationship with Microbial Biomass

Soil nitrogen mineralisation rates varied considerably with site, but were well within the range of values reported previously in the literature for nitrogen mineralisation (Mary *et al*., 1998). Fertilisation did not consistently influence the rates of nitrogen mineralisation, and this agreed with previously reported results in a laboratory-based study of the affects of nitrogen addition to forest soils, although in the same paper it was found that fertilisation statistically increased net nitrogen mineralisation rates in field-based experiments (Gurlevik *et al*., 2004). Increasing levels of organic matter removal were found to significantly decrease the rates of nitrogen mineralisation in soil samples taken from the different treatment plots, and this result was supported by Piatek and Allen (1999), who reported that net nitrogen mineralisation rates in stem only removal plots in a loblolly pine plantation were consistently greater than those in whole tree removal plots up to 15 years into the life of the next rotation.

A relatively strong positive relationship between nitrogen mineralisation and soil microbial biomass was found at Woodhill and Golden Downs (Table 3.9). This result agrees with that of Hart *et al*. (1986), who found a very strong positive relationship between anaerobically mineralised nitrogen and microbial biomass across a range of soils, although it must be noted that the measurement of microbial biomass in this case was based on carbon, not nitrogen. There was also a statistical relationship between nitrogen mineralisation and microbial biomass at Berwick, but only after the data was separated into fertilised and unfertilised plots (Table 3.9 and Figure 3.2). It was unclear why the relationship between nitrogen mineralisation and soil microbial biomass at Berwick was only strong after this division, and the only explanation that can be offered at this time was that the fertilisation treatment at Berwick resulted in a shift in the microbial community structure, with different statistical relationships between biomass and nitrogen mineralisation rates. However, this cannot be confirmed with the data provided in Chapter Three, and will be discussed in greater detail in Chapter Four. The relationship between soil microbial biomass and nitrogen mineralisation was suggested to be the mechanism responsible for the response of the nitrogen mineralisation rates to the organic matter removal treatments, as soil microbial biomass tended to be decreased by increasing levels of organic matter removal at the LTSP sites.

However, as nitrogen mineralisation was measured only once and at only three of the LTSP sites, these results cannot be considered to be definitive. Puri and Ashman (1998), measuring nitrogen mineralisation in a forest soil on multiple occasions, found that the relationship between soil microbial biomass and nitrogen mineralisation varied substantially with time, and it has been suggested that other parameters of the microbial community (Hassink *et al*., 1993; Smithwick *et al*., 2005) and physical and chemical environment (Piatek and Allen, 1999; Gurlevik *et al*., 2004) may be more accurate indicators of nitrogen mineralisation rates over a longer time frame.

3.4.6: Conclusions

The first hypothesis set out in the introduction of this chapter was partially confirmed, as it was found that the fertilisation treatments significantly decreased FH litter microbial biomass at the LTSP sites, with the exception of Kinleith, and this has been found to be the case in previous studies (Ohtonen *et al*., 1992). However, fertilisation did not consistently decrease soil microbial biomass at the LTSP sites, so this portion of the hypothesis was not satisfactorily proven.

The second hypothesis was also partially confirmed, as the organic matter removal treatments did not significantly influence FH litter microbial biomass, but it was found that soil microbial biomass tended to decrease significantly with increasing levels of organic matter removal. This effect of organic matter removal has been reported previously in the literature (Bååth, 1980; Bengtsson *et al*., 1998; Li *et al*., 2004), although it was evident that the magnitude of the response to increasing organic matter removal was greater at the LTSP sites than in these other studies, and consequently significant effects were produced more often in this study.

Consequently, it was concluded that microbial biomass at the LTSP sites was significantly influenced by the two treatment types, although the effects of fertilisation were only significant in the FH litter, and the organic matter removal treatments statistically influenced microbial biomass only in the soil. The reason for this division in the responses to the treatments was not clear, as fertilisation did not influence FH litter characteristics substantially more than soil characteristics when measured in summer 2002 (Table 2.10), and the organic matter removal treatments did not the influence the properties of the soil more than the FH litter (Table 2.11 and 2.12). An additional phenomenon of note was the response to fertilisation at Kinleith. Fertilisation decreased microbial biomass at the other sites in almost all cases, although not always significantly, but at Kinleith microbial biomass in both the FH litter and soil increased significantly in 2002 and 2003. It was not apparent why this increase was occurring, as the characteristics of the Kinleith site were not dissimilar to those of the five other LTSP sites (Refer Tables 1.1, 1.2 and 2.8).

The analysis of the FH litter and soil microbial biomass at the LTSP sites related the measurements of the physical and chemical environment with a relatively high degree of confidence in most cases, and these relationships were also able to provide mechanisms to explain the effects of the fertilisation and organic matter removal treatments on microbial biomass, where significant. These results confirmed the third hypothesis of this chapter, but it must be stated that the nature of the relationships between the physical and chemical parameter of the LTSP environment and the effects of the fertilisation and organic matter removal treatments on microbial biomass may have been better understood if all parameters (such as soil pH) were measured in all of the sampling rounds.

Based on the results of the nitrogen mineralisation experiments, it was concluded that organic matter removal did significantly decrease rates of nitrogen mineralisation, and that there was a significant positive relationship between soil microbial biomass and nitrogen mineralisation, confirming the fourth hypothesis of this chapter. However, as mineralisation was only measured on one occasion and at a limited number of sites, it was also strongly recommended that additional sampling at different times of year be carried out to determine if the relationship between microbial biomass and nitrogen mineralisation remained constant with time.

Overall, the fluctuations of the FH litter and soil microbial biomass in response to the treatments were best considered in terms of the nature of microbial biomass itself. Microbial biomass is under constant flux, varying with the factors that influence it (Wardle, 1992, 1998a), and consequently it was hypothesised that the application of the treatments at the LTSP sites had altered the environmental factors important to regulating microbial biomass. However, it was considered more accurate to suggest that the treatment applications had created environmental differences that had the potential to produce significant differences in microbial biomass, but only when a critical point was reached in a broader environmental parameter, such as moisture availability. Hypothetically, if available moisture levels remained above a certain point, the differences induced by treatments were not important, but if moisture availability fell below this point, the differences between the treatment plots started to influence microbial biomass. This concept was supported by the annual differences in soil microbial biomass in particular, as soil microbial biomass was positively related to soil moisture content, and in 2003 when moisture levels at the LTSP sites were generally decreased, more significant differences were found between the levels of the organic matter removal treatment, which has been found to strongly influence soil moisture content.

CHAPTER FOUR: EFFECTS OF FERTILISATION AND ORGANIC MATTER REMOVAL ON MICROBIAL DIVERSITY

4.1: INTRODUCTION

As previously discussed, the various functions of plant litter and soil microbial communities are critical to all terrestrial ecosystems, and in order to develop effective long-term sustainable land management strategies, it is important to determine how microbial communities have been shaped by the environment they develop in, how they respond to alterations to that environment, and how the functions of the community may be affected (Brussaard *et al*., 1997; Kennedy and Gewin, 1997; Wall and Moore, 1999).

One of the parameters of terrestrial microbial communities that has been the focus of considerable research in recent years, and has the potential to be very important to future sustainable land management practices, is the diversity of the microbial species that constitute microbial communities (Kennedy and Gewin, 1997; Ajwa *et al*., 1999; Staddon *et al*., 1999; Wardle *et al*., 2001). Microbes are a very diverse group of organisms, and the range of the microbial species inhabiting the plant litter and soil environment in a given terrestrial ecosystem is considerable (Kennedy and Gewin, 1997). Initially, assessments of microbial community diversity were based around culturing, isolating and identifying species from samples of plant litter and soil, but as a consequence, only organisms able to be cultured in the laboratory were included in the measurements of diversity, leaving an unknown proportion of the microbial community unidentified and unaccounted (Perfilev and Gabe, 1969; Bakken, 1985; Tunlid and White, 1992). Additionally, the natural variation and complexity of the plant litter and soil environment and the scale of microbial life combine to generate innumerable distinct microhabitats, increasing the spatial variability of microbial diversity in the forest floor (Parkin, 1993; Ohtonen *et al*., 1997). More recently, the development and application of new techniques, such as the detection of nucleic acids and molecular markers associated with particular microbial species and studies into the range of substrates utilised by microbial communities have increased the ability of researchers to accurately describe and compare microbial community diversity (Borneman *et al*., 1996; Kennedy and Gewin, 1997; Reynolds *et al*., 2003).

The information provided by studies into microbial diversity in terrestrial ecosystems has significant value to both ecological and applied research. Assessments of microbial diversity in plant litter and soil using species specific molecular markers in undisturbed environments allows the range of native microbial species present in an ecosystem to be determined, and the impact of natural variations, such as seasonal changes, can also be resolved (Garland and Mills, 1991; Hedin *et al*., 1995; Dunbar *et al*., 2000; Poly *et al*., 2001). In managed ecosystems, the effects of anthropogenic disturbances on microbial diversity can also be assessed, which is of increasing importance as legislative initiatives regarding the identification and preservation of native diversity become more commonplace in New Zealand and around the world (Fox, 2000; Smith *et al*., 2000). However, the greatest benefits of determining microbial species diversity are potentially in linking diversity with function. It has long been suggested that there is a relationship between the diversity of a microbial community and the various ecosystem processes that are carried out by that community, known as functional diversity, but this can only be assessed if the species diversity of the community is established (Kennedy and Gewin, 1997).

Theoretically, accurately relating the functional diversity of a microbial community to the species diversity potentially allows the impacts of disturbances, which alter the species diversity, to be better understood and planned for in terms of the overall ecosystem processes (Parkinson and Coleman, 1991; Wardle and Giller, 1996; Groffman and Bohlen, 1999; Adams and Wall, 2000). However, this concept is complicated by the potential for redundancy in the microbial community, as some processes may be carried out by a number of species, and therefore these processes may effectively be more resistant to disturbance than others (Brussaard *et al*., 1997; Chapin *et al*., 1997; Naeem and Li, 1997; Nannipieri *et al*., 2003), although this concept is itself contentious (Wardle, 1998b).

The impacts of fertilisation regimes, tree harvesting and other aspect of forestry management on forest floor and soil microbial community diversity have been examined in various studies, but conflicting results have often been produced (Jonsson *et al*., 2000; Peter *et al*., 2001). It has been suggested that the potential for alterations in microbial community diversity at a given site may be influenced by the environmental conditions, such as soil pH, nutrient availability and the initial characteristics of the soil microbial community itself, explaining some of this variation in response (Lee and Jose, 2003).

Consequently, the aim of this chapter is to determine if the fertilisation and organic matter removal treatments applied at the six LTSP sites have resulted in the establishment of measurably different FH litter and soil microbial communities in the treatment plots, based on patterns and rates of substrate utilisation by the community. Furthermore, the relationship between microbial diversity and parameters of the physical and chemical environment and microbial biomass will be investigated, to determine if any variations in microbial diversity can be related to the conditions at the LTSP sites. Accordingly, the hypotheses that will be investigated in this chapter are:

1. That there are differences in the microbial community structure at the different LTSP sites, as characterised by substrate utilisation profiles.
2. That microbial community structure in the FH litter and soil, as characterised by substrate utilisation profiles, is significantly different between fertilised and unfertilised plots at the LTSP sites.
3. That microbial community structure in the FH litter and soil, as characterised by substrate utilisation profiles, is significantly different between the different organic matter removal treatment plots at the LTSP sites.
4. That the FH litter and soil microbial substrate utilisation patterns can be statistically related to the physical and chemical environment and microbial biomass, and provide a basis for any shifts in community structure induced by fertilisation or organic matter removal.

4.2: METHODS AND MATERIALS

As discussed earlier, various techniques to accurately assess microbial diversity in forest soils have been developed in recent years. The method that was predominantly employed in this study was the Biolog system (Biolog Inc.), which indirectly characterises microbial community diversity based on patterns of substrate utilisation, using a measure of the functional diversity of the community to produce a catabolic profile related to the actual species diversity (Zak *et al*., 1994). Variations in the patterns of substrate utilisation by the microbial communities sampled from different sites or treatment plots can be used to assess the relative diversity of the microbial communities, and the statistical significance of any variations can also be determined.

It has been determined that the majority of the substrate utilisation observed in Biolog plates is the result of the activity of the bacterial component of the microbial community, as bacterial species generally multiply more rapidly than fungal species in the conditions of the Biolog plates (Preston-Mafham *et al*., 2002). For the purposes of this study, this was not important, as the substrate utilisation data generated with the Biolog plates were only intended to be indirect parameters describing the relative differences in microbial community diversity between sites and treatments, rather than direct measurements of actual bacterial and fungal species diversity or substrate utilisation in the forest floor environment.

The operational principles of the Biolog system are as follows. Samples of the microbial community are inoculated into wells containing a single substrate. If the community is capable of metabolising the substrate, the associated respiration reduces a tetrazolium dye included with the substrate, resulting in a measurable colour change. By determining the range of substrates utilised by a microbial community, and the rate at which they are utilised, the catabolic profile of the community can be generated. Biolog plates were first employed in microbial community analysis by Garland and Mills (1991), and have subsequently been used in various research projects to compare microbial community structure across different ecosystems, sites and treatments levels (Dhillion *et al*., 1996; Sarathchandra *et al*., 2001; Grayston and Prescott, 2005). The type of Biolog plate used in this study is described below, as is the procedure for sample preparation and plate inoculation and incubation.

4.2.1: Biolog Plate Substrates

Biolog EcoPlates were used in this study, as these plates were designed to assess community structure rather than to identify particular microbial species. Each plate contained 96 micro titre wells, divided into three replicated sets. The 32 wells in each of the sets contained a different substrate, and also a blank control well containing nothing. The layout of the substrates in the EcoPlates is shown in Figure 4.1.

Figure 4.1: Biolog EcoPlate Substrate Set Layout

Blank	β-Methyl-D-Glucoside	D-Galactonic Acid γ-Lactone	L-Arginine
Pyruvic Acid Methyl Ester	D-Xylose	D-Galacturonic Acid	L-Asparagine
Tween 40	i-Erythritol	2-Hydroxy Benzoic Acid	L-Phenylalanine
Tween 80	D-Mannitol	4-Hydroxy Benzoic Acid	L-Serine
α-Cyclodextrin	N-Acetyl-D-Glucosamine	γ-Hydroxybutyric Acid	L-Threonine
Glycogen	D-Glucosaminic Acid	Itaconic Acid	Glycyl-L-Glutamic Acid
D-Cellobiose	Glucose-1-Phosphate	α-Ketobutyric Acid	Phenylethylamine
α-D-Lactose	D,L-α-Glycerol Phosphate	D-Malic Acid	Putrescine

The 31 substrates were also divided into four broad groups, based on the nature of the molecules, as indicated by the colours in Figure 4.1. The substrate groups were as follows:

GREEN	Carbohydrates
YELLOW	Nitrogen and Phosphorous Sources
BLUE	Carboxylic Acids
PURPLE	Amino Acids

4.2.2: Sample Preparation and Plate Inoculation

The FH litter and soil samples used to inoculate the Biolog EcoPlates were subsampled from the bulked fresh samples from each sampling round as described in Section 2.2. For both FH litter and soil samples, 5 gm of fresh material (± 20 mg) was weighed into 250 ml flasks, and then 100 ml of distilled double deionised water (ddH_2O) was added to the flasks. The flasks were then sealed and placed on an orbital shaker for 30 minutes to ensure all of the sample material was exposed to the water. After shaking, the contents of the flasks were poured through Whatman No. 1 filter paper into a second set of flasks, which were then sealed and placed into a laminar flow cabinet. The Biolog EcoPlates were opened inside the laminar flow cabinet, and 100μl of the filtrate was dispensed into all 32 wells in one of the substrate sets, allowing the filtrates from three samples to be incubated on each EcoPlate. After all wells had been inoculated, the EcoPlates were sealed.

4.2.3: Plate Incubation and Substrate Utilisation Measurements

After inoculation, the EcoPlates were placed in an incubator and kept at 12^{o}C for 120 hours. After this time, the plates were removed from the incubator, and placed in an automated microplate reader (Model EL309, BIO-TEK Instruments Inc.) and the optical density at 540nm in each well was measured. The EcoPlates were then removed from the plate reader, and returned to the incubator for a further 120 hours, after which time a second plate reading was performed.

4.2.4: Data Treatment and Statistical Analyses

The raw absorbance data from each plate was transferred from the plate reader to a spreadsheet, and in each of the sets of 32 wells, the absorbance value for the blank well was subtracted from the absorbance values for the other 31 wells. This blanked absorbance value for each well was then converted to express the absorbance per gram of oven dry, ash free FH litter or oven dry soil, to account for the differences in the moisture content in the 5 gm of fresh material used to inoculate the plates.

The two main statistical analyses performed on the substrate utilisation data for the FH and soil microbial communities were Principal Component Analysis (PCA) and ANOVA. PCA was performed to characterise the microbial communities based on the variability in the utilisation of the 31 substrates. The variation of the individual substrates in the four substrate groups was also assessed in this way. All PCA was performed using Multi Variate Statistical Package Version 3.10a (Kovach Computing Services) and ANOVA and Multiple comparison analysis (Tukey's) were then used to determine the statistical significance of the PCA outputs. ANOVA and Tukey's test, as described in Section 2.2.5, were also used to determine if the total amount of substrate utilisation by the microbial community in a given plot varied statistically with time and treatment type. Separate totals for each of the substrate groups (Figure 4.1) were also calculated and analysed with ANOVA. Multiple stepwise regression was used to identify any statistical relationships between the physical, chemical and microbial biomass data produced in Chapters Two and Three and the total substrate utilisation for all 31 substrates and the total utilisation for each of the substrate groups in each sampling round.

4.3: RESULTS

Several PCA plots are presented, illustrating the variations in the structure of the FH litter and soil microbial communities at the different LTSP sites, and the response of the communities to the treatments The degree of variation explained by the two principal component axes of each PCA plot is given, as are the eigenvalues of each axis. The ANOVA analyses of the distribution of the data points on the principal axis (horizontal axis) of every PCA are given in Statistical Appendix Three (S. App. 3).

The mean values for total substrate utilisation across all sites are presented in Tables 4.1 –4.6, with the standard error of the mean (SEM) given in italics and a letter or letters indicating statistical differences in mean substrate utilisation. Full summaries of the ANOVA calculations used to determine the significance of the differences in the mean values are given in Statistical Appendix Four (S. App. 4). The abbreviated terms used in the plots and tables to describe the sites, utilisation measurements and substrate groups are as follows:

BE	Berwick
BU	Burnham
GD	Golden Downs
KIN	Kinleith
TAR	Tarawera
WH	Woodhill
F120	FH litter microbial community after 120 hours incubation
F240	FH litter microbial community after 240 hours incubation
S120	Soil microbial community after 120 hours incubation
S240	Soil microbial community after 240 hours incubation
AA	Mean utilisation of amino acids
CARB	Mean utilisation of carboxylic acids
CHO	Mean utilisation of carbohydrates
NP	Mean utilisation of nitrogen and phosphorous sources

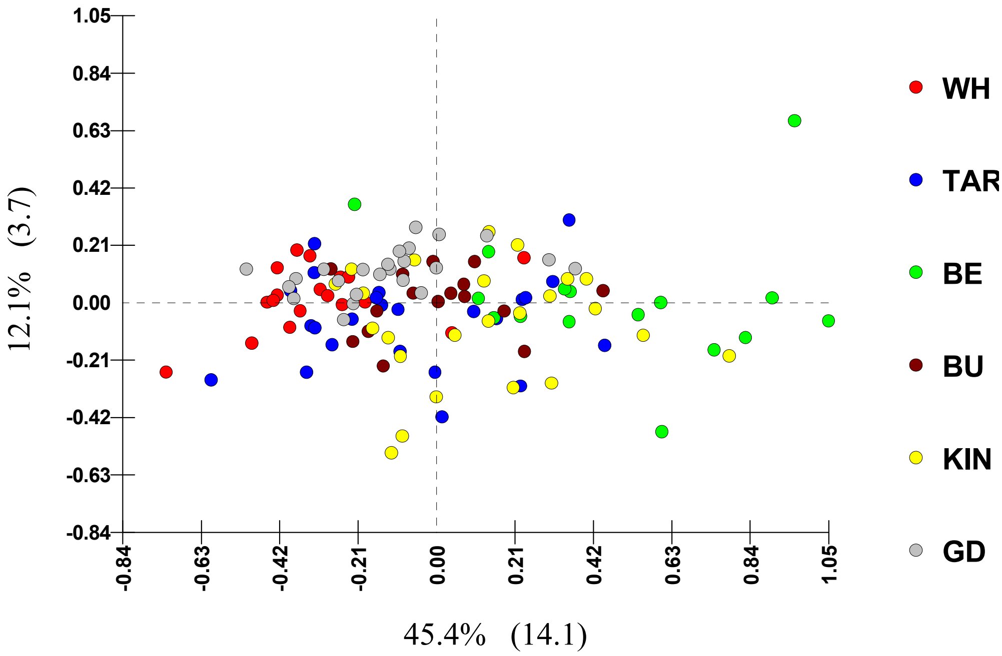
The substrate utilisation regression models for each site and sampling round are presented last, and the parameters, coefficients and intercepts used in the models are given. In cases where multiple parameters are statistically significant, they are ranked in order of importance to the regression model.

4.3.1: Variations in Substrate Utilisation Patterns Between LTSP Sites

FH Litter Microbial Communities

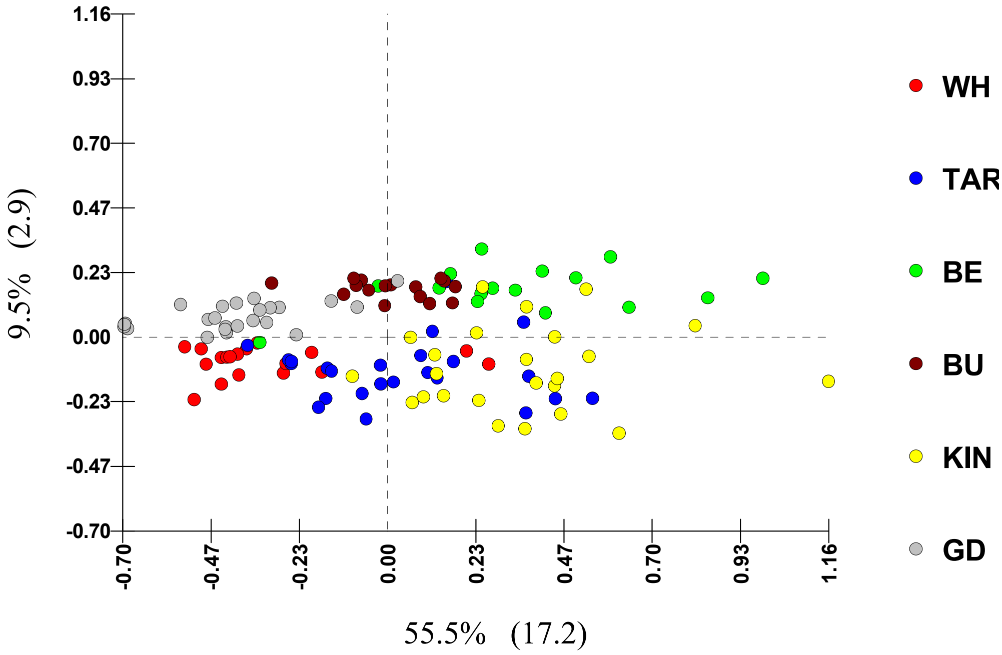
The variation in substrate utilisation by the FH litter microbial community at the six different LTSP sites is shown in Figures 4.2 – 4.5. Each data point in the plots represents a single treatment plot, and the relative position of the points indicated the level of similarity in substrate utilisation. In general, the degree of variation in substrate utilisation explained by the second principal (vertical) axis in the PCA plots was not substantial, and consequently any significant differences along this axis were not reported.

Figure 4.2: Utilisation Patterns after 120 Hours Incubation – Summer 2002



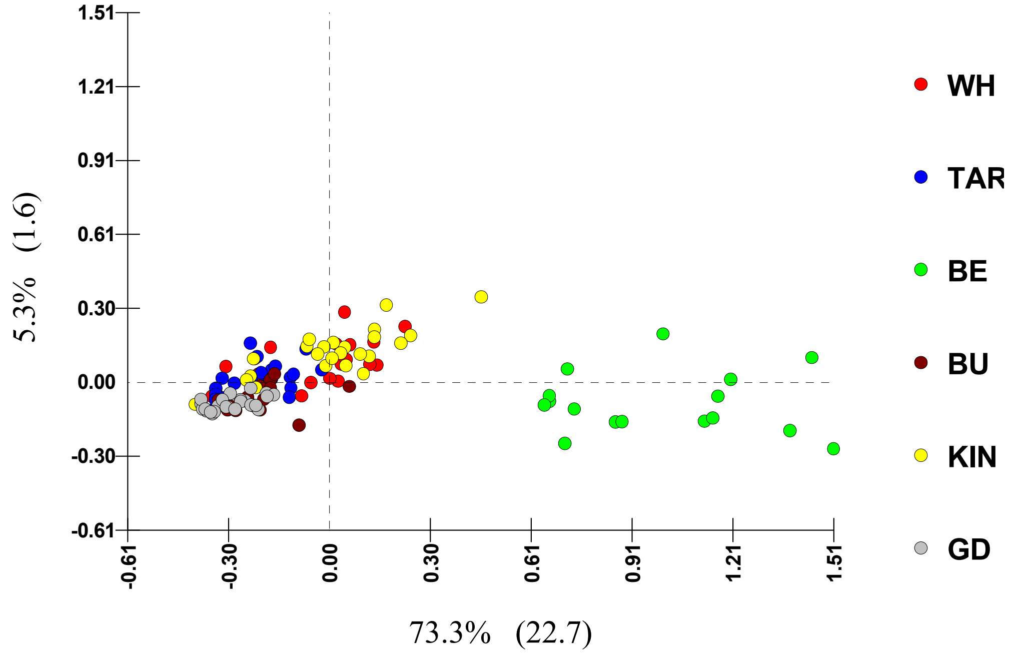
The wide distribution of data points in Figure 4.2 indicated that substrate utilisation by the FH litter microbial communities in the treatment plots in the summer 2002 sampling round varied considerably within each of the LTSP sites. Despite this, substrate utilisation at Berwick was found to be statistically different from that at the five other LTSP sites, based on the relative positions of the data point on the principal axis (S. App. 3.1.1). The utilisation patterns at Woodhill were also significantly different to all of the other sites with the exception of Golden Downs, which was significantly distinct from Kinleith on the principal axis. The degree of variation in substrate utilisation explained by the principal axis was only 45.4% of the total variation, and this suggested that although there were significant differences between the sites along this axis, confidence in the accuracy of the axis itself was not great.

Figure 4.3: Utilisation Patterns after 240 Hours Incubation – Summer 2002



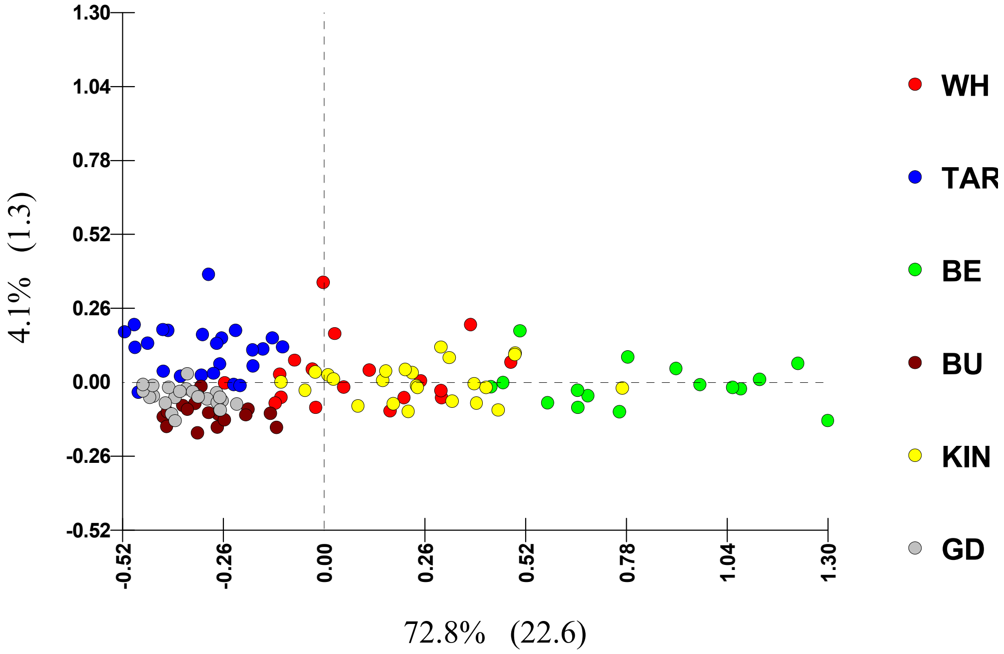
The differences between the LTSP sites along the principal axis were more distinct after a further 120 hours incubation of the plates, as shown in Figure 4.3. Three statistically separate pairs of sites were identified in the PCA plot, as similar substrate utilisation patterns were found at Golden Downs and Woodhill, Burnham and Tarawera, and Berwick and Kinleith (S. App. 3.1.1). The degree of variation in substrate utilisation in the Biolog plates explained by the principal axis was increased by 10% after the additional period of incubation, improving confidence in the veracity of the statistical differences, but a large degree of variation was still unaccounted for.

Figure 4.4: Utilisation Patterns after 120 Hours Incubation – Summer 2003



The data points in Figure 4.4 representing the patterns of substrate utilisation at the LTSP sites by the FH litter microbial communities in summer 2003 after 120 hours incubation formed three statistically separate groups along the principal axis (S. App. 3.1.1). The patterns of utilisation at Berwick were statistically distinct from those at the five other sites, and the substrate utilisation patterns of the microbial communities sampled from the Kinleith and Woodhill treatment plots were the same as each other, but different from the other LTSP sites. Burnham, Golden Downs and Tarawera formed the third statistical grouping. The degree of variation in substrate utilisation explained by the principal axis in Figure 4.4 was substantial, and consequently the statistical differences in the relative patterns of substrate utilisation between the six LTSP sites in the Biolog plates were considered to be accurate.

Figure 4.5: Utilisation Patterns after 240 Hours Incubation – Summer 2003



As in 2002, the separation along the principal axis between the groups of data points representing the six LTSP site treatment plots increased after a further 120 hours incubation of the plates, and statistical differences between the sites also increased. The patterns of substrate utilisation in the Biolog plates by the FH litter microbial communities collected from each of the Berwick, Woodhill and Kinleith sites were significantly different to the five other LTSP sites, and the patterns of utilisation at Burnham, Golden Downs and Tarawera were the same. The variation in substrate utilisation explained by the principal axis was slightly decreased by the additional 120 hours incubation, but was still very high, and there was a high degree of confidence in the accuracy of the statistical findings.

The 2003 PCA plots explained substantially more variation than the 2002 PCA plots, and were therefore more accurate. There were several statistical changes in the differences between the sites, and this can be seen in the variations in the position of the data points representing the Burnham, Tarawera and Woodhill sites in Figure 4.3 and 4.5 in particular, but overall the relative positions of the sites in the plots did not alter radically between 2002 and 2003.

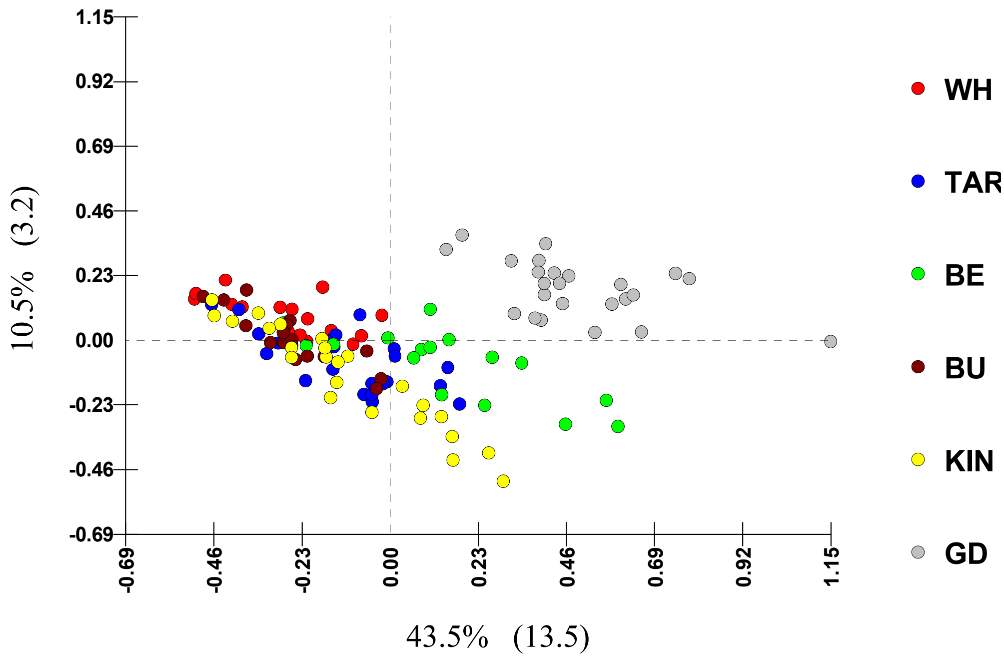
The PCA plots generated to assess the variability in the utilisation of the four substrate groups in each of the sampling rounds and after 120 and

240 hours incubation did not differ substantially from the PCA plots describing utilisation for all substrates combined (Figures 4.2 – 4.5). A number of differences in the relative positions of the sites were detected, but in general the statistical differences between the sites did not differ in the PCA plots of utilisation of the different substrate groups (S. App. 3.1.2 – 3.1.5), and the degree of variation explained by the PCA plots of the individual substrate groups was similar to the variation explained in the PCA plots of all 31 substrates.

Soil Microbial Communities

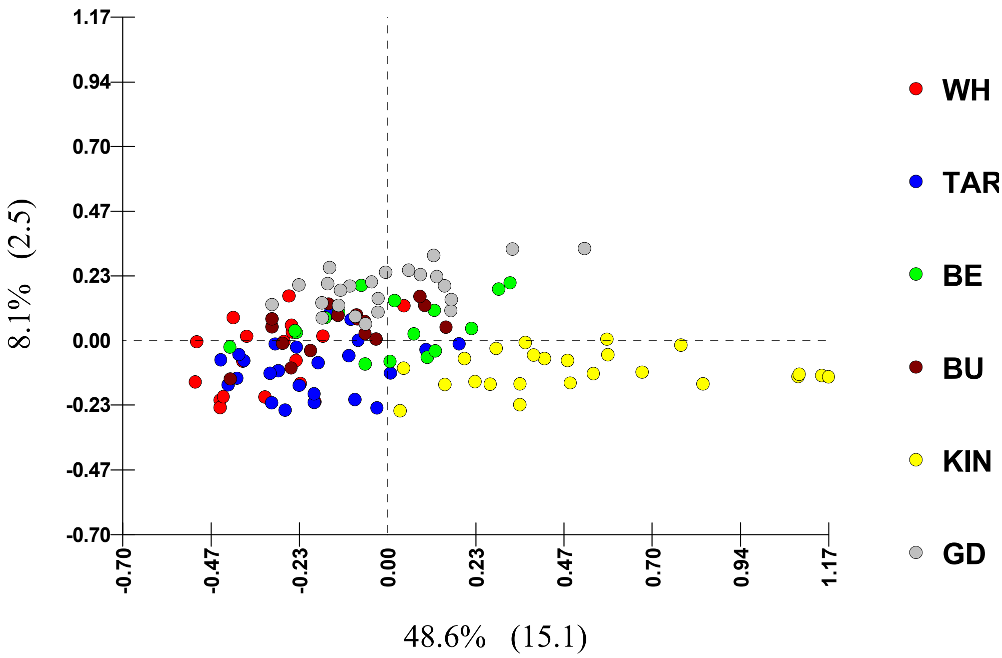
The PCA plots describing the patterns of substrate utilisation by the soil microbial communities from samples collected at the six LTSP sites in the summer 2002 and 2003 are shown in Figures 4.6 – 4.9. As with the PCA plots describing substrate utilisation by the FH litter microbial community, the degree of variation in utilisation explained by the vertical axis in the PCA plots was negligible, and any significant differences between the sites along this axis were not considered.

Figure 4.6: Utilisation Patterns after 120 Hours Incubation – Summer 2002



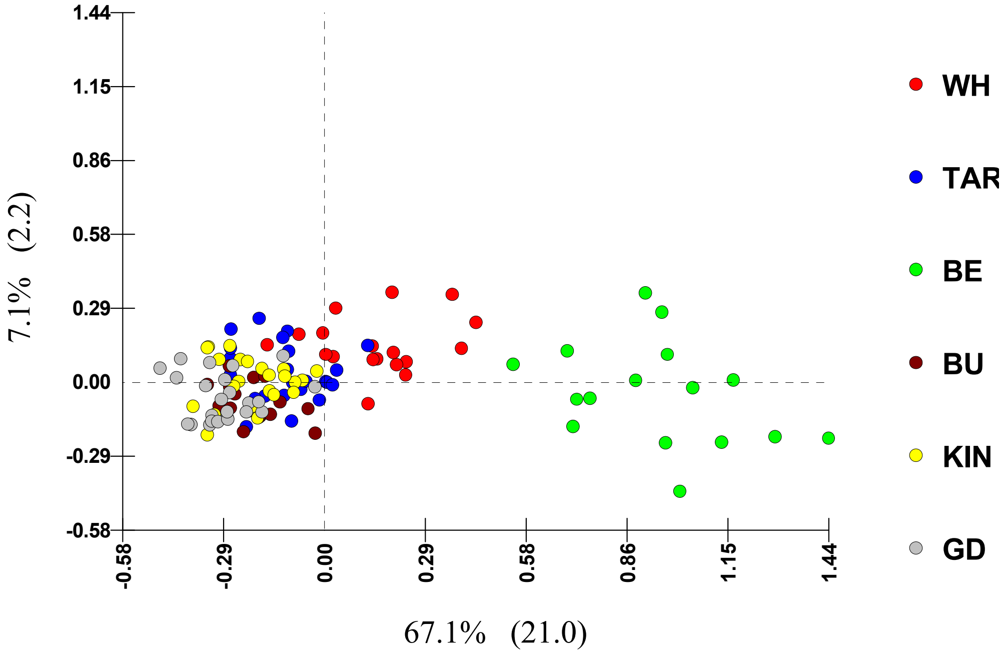
The statistical analysis of the distribution of the data points along the principal axis in Figure 4.6 determined that the patterns of utilisation by the soil microbial communities at Berwick and Golden Downs were distinct from each other and the four other LTSP sites (S. App. 3.1.1), but there were no significant differences in substrate utilisation between Burnham, Kinleith, Tarawera and Woodhill after 120 hours incubation in the Biolog plates. The variation in utilisation explained by the principal axis was only 43.5%, leaving a large portion of variation unaccounted for, and provided little confidence in the accuracy of the PCA and the statistical differences between the sites.

Figure 4.7: Utilisation Patterns after 240 Hours Incubation – Summer 2002



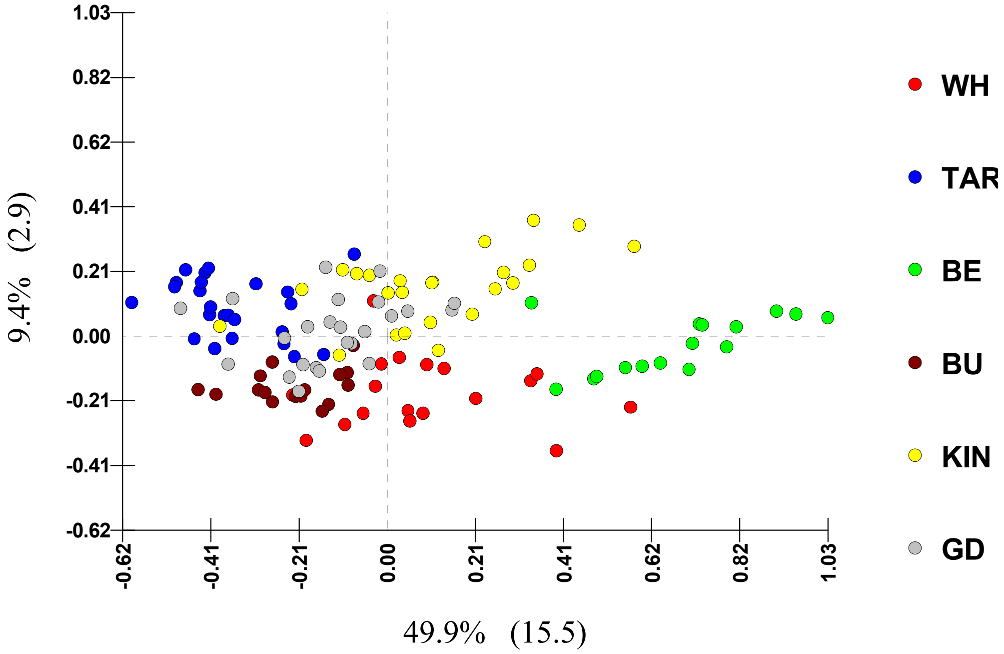
The incubation of the Biolog plates for a further 120 hours altered both the patterns of substrate utilisation at the individual sites and the statistical relationships between the sites (Figure 4.7). Substrate utilisation patterns at Kinleith were significantly different to the five other sites, which formed an overlapping continuum of data points along the principal axis. Within this continuum, Berwick and Golden Downs were statistically distinct form Woodhill, and utilisation by the Golden Downs soil microbial community was also statistically different that of the Tarawera community. The degree of variation in utilisation explained by the principal axis in Figure 4.7 was not substantially influenced by the increased period of incubation, and was not considerable.

Figure 4.8: Utilisation Patterns after 120 Hours Incubation – Summer 2003



The data points in Figure 4.8 representing substrate utilisation by the soil microbial communities collected from the Burnham, Kinleith, Golden Downs and Tarawera treatment plots in summer 2003 were all tightly grouped, and occupied approximately the same range on the principal axis. This was reflected in the statistical analysis of the differences between the sites (S. App. 3.1.1), which determined that the utilisation patterns at Berwick were distinct to those at the five other LTSP sites, as did the utilisation patterns of the soil microbial community sampled at Woodhill. Substrate utilisation also differed significantly between the Golden Downs and Tarawera sites. The total degree of variation in utilisation explained by the principal axis of the PCA plots was substantial, accounting for 67.1% of the total variation in the utilisation of the 31 substrates.

Figure 4.9: Utilisation Patterns after 240 Hours Incubation – Summer 2003



As in 2002, the data points in Figure 4.9 indicated that patterns of utilisation by the soil microbial communities were altered by a further 120 hours incubation. The relative distribution of the Berwick data points was unchanged, and the site was still statistically distinct from the five other LTSP sites (Pr (F) = 0.00), but the relative locations on the principal axis and statistical relationships between the five others sites was altered. Kinleith and Woodhill were statistically distinct to all other sites with the exception of each other, and although the patterns of substrate utilisation of the Golden Downs soil microbial community were still different to the Tarawera soil microbial community, the relative positions of the two sites on the plots was reversed in Figure 4.9. The degree of variation in substrate utilisation explained by the principal axis of the PCA plots was reduced by 17% after 240 hours, decreasing confidence in the accuracy of the analysis.

The relative locations of the sites in the PCA plots of soil microbial community substrate utilisation varied with year of sampling, and there were more statistical differences between the individual sites in the plots. More variation was explained in 2003 than in 2002 after 120 hours incubation (Figures 4.6 and 4.8), but the difference after 240 hours was not great.

The distribution of the data points and the statistical relationships between the sites in the PCA plots calculated for the carbohydrate and nitrogen and phosphorus source substrate groups tended to be the same as in Figures 4.6 – 4.9, but the utilisation patterns for amino acids (Figure 4.10) and carboxylic acids (Figure 4.11) in 2002 tended to display a greater degree of intra-site variability than the relevant PCA plots for all 31 substrates, and fewer significant differences between the LTSP sites were calculated.

Figure 4.10: Utilisation of Amino Acids after 120 Hours Incubation – Summer 2002

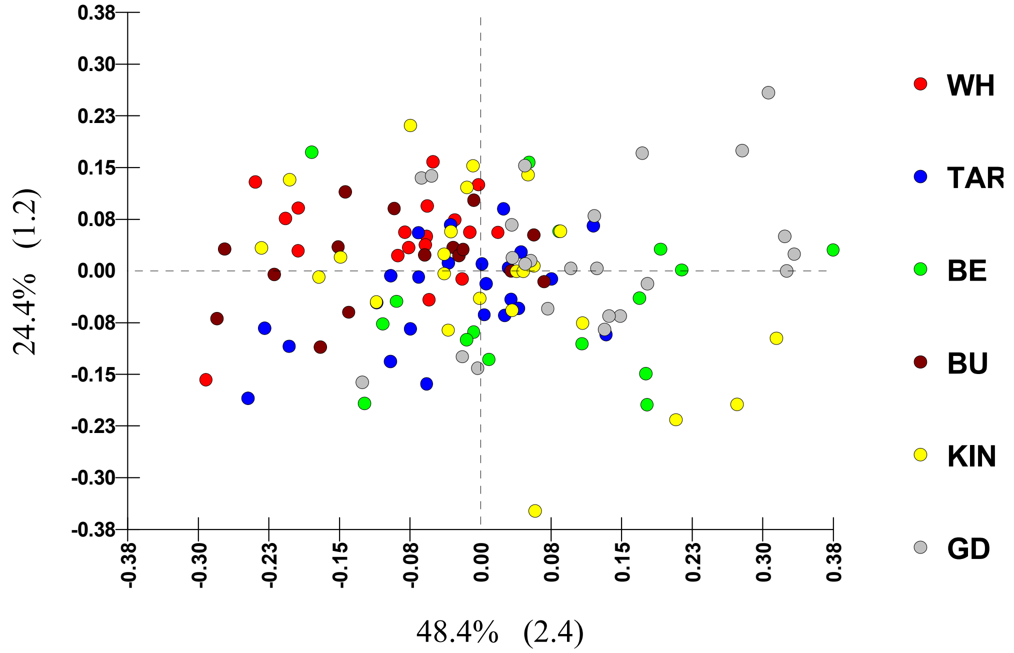
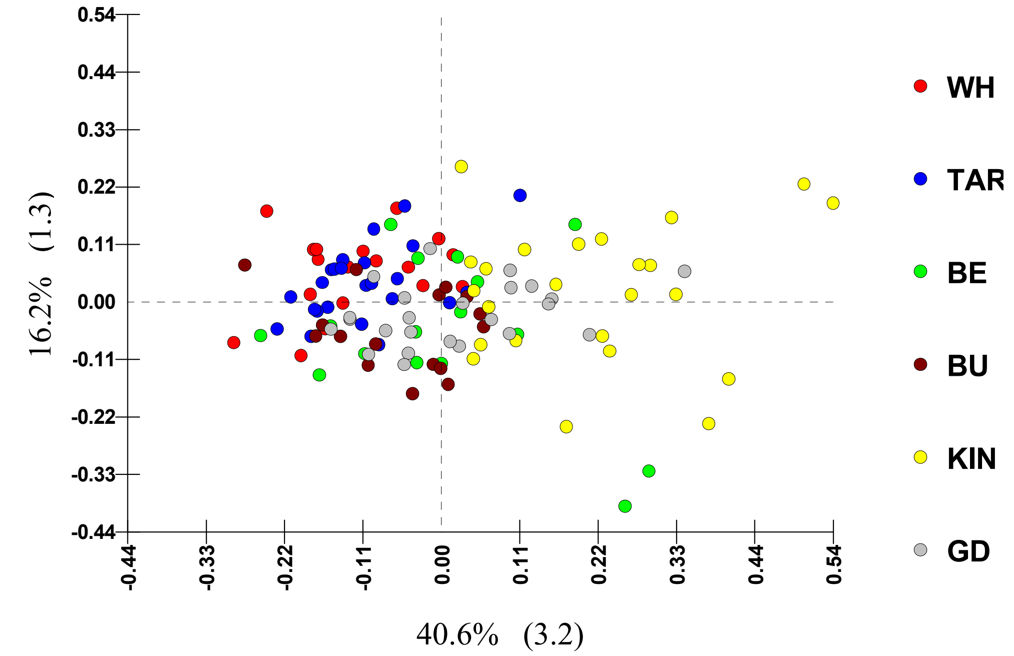


Figure 4.11: Utilisation of Carboxylic Acids after 240 Hours Incubation – Summer 2002



4.3.2: Effects of Fertilisation on FH Litter and Soil Microbial Community Total Substrate Utilisation

Table 4.1: Effects of Fertilisation on Total Substrate Utilisation by the FH Litter Microbial Community

	F120	F240	F120 AA	F120 CARB	F120 CHO	F120 NP	F240 AA	F240 CARB	F240 CHO	F240 NP
SUMMER 2002										
FERT	7.83	15.26	1.52	1.99	2.28	2.04	2.45	2.93	6.27	3.61
	(0.35)	(0.55)	(0.07)	(0.09)	(0.11)	(0.09)	(0.09)	(0.12)	(0.24)	(0.13)
NO FERT	7.81	14.82	1.45	1.99	2.35	2.01	2.31	2.91	6.10	3.51
	(0.41)	(0.64)	(0.07)	(0.11)	(0.14)	(0.10)	(0.10)	(0.14)	(0.28)	(0.14)
SUMMER 2003										
FERT	5.84 **a**	9.81	1.09 **a**	1.44 **a**	1.83	1.48 **a**	1.63 **a**	2.10 **a**	3.83	2.25
	(0.55)	(0.61)	(0.09)	(0.12)	(0.23)	(0.12)	(0.09)	(0.13)	(0.27)	(0.13)
NO FERT	5.28 **b**	9.23	0.98 **b**	1.25 **b**	1.70	1.35 **b**	1.51 **b**	1.92 **b**	3.62	2.19
	(0.52)	(0.57)	(0.08)	(0.12)	(0.22)	(0.11)	(0.09)	(0.12)	(0.24)	(0.12)

Letters in bold indicate statistical groupings based on Tukey’s multi-comparison analysis test

Table 4.2: Effects of Fertilisation on Total Substrate Utilisation by the Soil Microbial Community

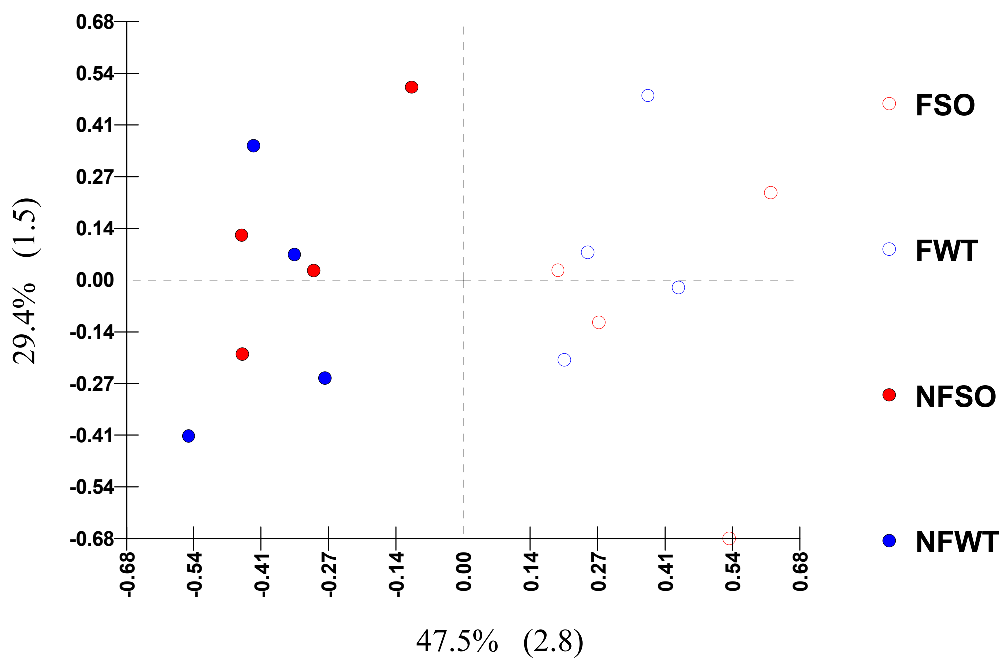
	S120	S240	S120 AA	S120 CARB	S120 CHO	S120 NP	S240 AA	S240 CARB	S240 CHO	S240 NP
SUMMER 2002										
FERT	4.85	9.01	0.95	1.18	1.50	1.20	1.41	1.82	3.62	2.15
	(0.22)	(0.36)	(0.03)	(0.06)	(0.10)	(0.05)	(0.05)	(0.08)	(0.16)	(0.09)
NO FERT	5.06	9.22	0.97	1.26	1.58	1.25	1.40	1.86	3.74	2.21
	(0.26)	(0.29)	(0.03)	(0.07)	(0.11)	(0.06)	(0.04)	(0.07)	(0.13)	(0.07)
SUMMER 2003										
FERT	2.80	6.03	0.62	0.64	0.82	0.72	1.12	1.28	2.12	1.51
	(0.31)	(0.29)	(0.05)	(0.08)	(0.12)	(0.08)	(0.05)	(0.07)	(0.13)	(0.07)
NO FERT	2.80	6.07	0.60	0.66	0.84	0.71	1.07	1.27	2.26	1.47
	(0.30)	(0.26)	(0.03)	(0.06)	(0.09)	(0.05)	(0.04)	(0.06)	(0.12)	(0.06)

Letters in bold indicate statistical groupings based on Tukey’s multi-comparison analysis test

Effects of Fertilisation on the FH Litter Microbial Communities

In 2002, fertilisation did not statistically influence mean total substrate utilisation by the FH litter microbial community (Table 4.1). The effect of fertilisation was substantially stronger in summer 2003, as the mean total utilisation values were significantly increased by fertilisation for all substrates combined after 120 hours incubation (F120), and were almost statistically different after 240 hours incubation as well (Pr (F) = 0.076). Of the four substrate groups, fertilisation significantly increased the capability of the FH litter microbial community to utilise amino acids and carboxylic acids after 120 and 240 hours incubation in the plates, and the utilisation of the nitrogen and phosphorous source substrate group was also statistically increased after 120 hours incubation. The PCA plots of utilisation by the FH litter microbial communities sampled from the individual sites indicated that fertilisation significantly influenced patterns of substrate utilisation at Burnham, and this was observed most strongly in the utilisation of amino acids (Figure 4.12).

Figure 4.12: Utilisation of Amino Acids by Burnham FH Litter Microbial Community after 240 Hours Incubation – Summer 2003



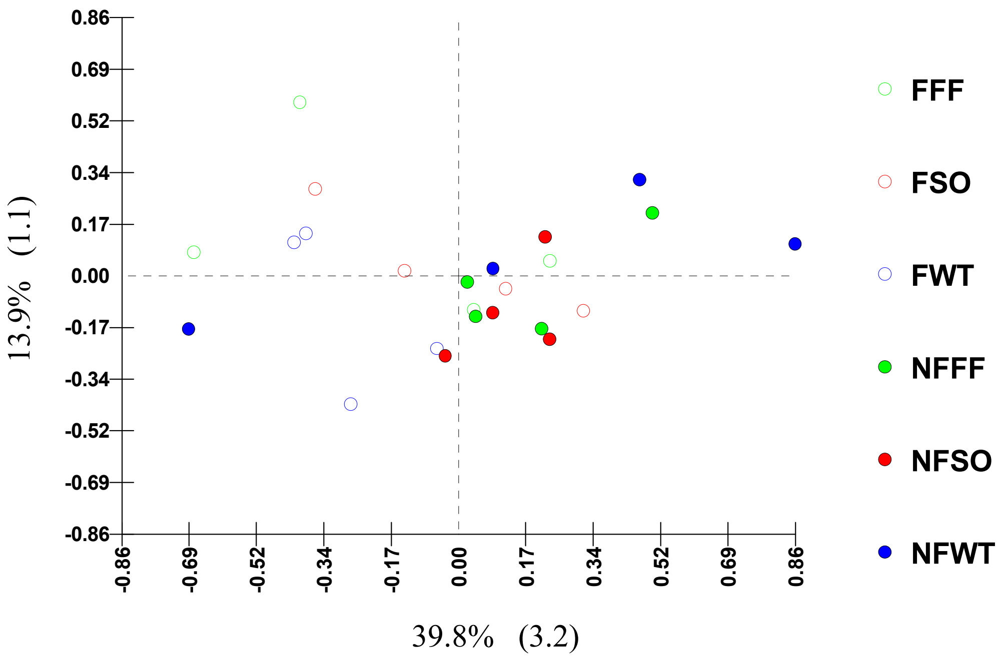
The utilisation of substrates by the FH litter microbial community was also influenced by fertilisation at Berwick in 2002 and Kinleith in 2003 (S. App 3.4 and 3.6). Fertilisation did not significantly affect substrate utilisation patterns at Woodhill, Tarawera or Golden Downs in either year.

Effects of Fertilisation on the Soil Microbial Communities

Fertilisation did not significantly affect the mean substrate utilisation by the soil microbial community in 2002 or 2003 (Table 4.2). Utilisation by microbial communities from fertilised plots tended to be slightly lower in 2002, but the difference in mean values was not substantial and did not approach statistical significance.

Several significant differences were found in the patterns of substrate utilisation by the soil microbial communities sampled from fertilised and unfertilised plots at Tarawera (S. App. 3.3). The utilisation patterns of the soil microbial sampled from Woodhill, Berwick and Kinleith were also influenced by the fertilisation treatment in several cases (S. App. 3.2, 3.4 and 3.6), although the utilisation patterns at Tarawera were most often affected by fertilisation (Figure 4.13). The utilisation patterns of soil microbial communities sampled from Burnham or Golden Downs were unaffected.

Figure 4.13: Utilisation of Carboxylic Acids by Tarawera Soil Microbial Community after 120 Hours Incubation – Summer 2002



4.3.3: Effects of Organic Matter Removal Treatments on FH Litter and Soil Microbial Community Substrate Utilisation

Table 4.3: Effects of Whole Tree and Stem Only Removal Treatments on Total Substrate Utilisation by the FH Litter Microbial Community

	F120	F240	F120 AA	F120 CARB	F120 CHO	F120 NP	F240 AA	F240 CARB	F240 CHO	F240 NP
SUMMER 2002										
WT	8.14	15.61	1.55	2.10	2.39	2.10	2.48	3.00	6.46	3.67
	(0.47)	(0.70)	(0.08)	(0.13)	(0.16)	(0.11)	(0.12)	(0.16)	(0.30)	(0.16)
SO	8.28	15.61	1.59	2.09	2.44	2.15	2.43	3.03	6.43	3.72
	(0.42)	(0.61)	(0.08)	(0.11)	(0.15)	(0.10)	(0.10)	(0.12)	(0.28)	(0.14)
SUMMER 2003										
WT	6.14	10.24	1.13	1.48	2.02	1.51	1.69	2.16	4.03	2.36
	(0.73)	(0.79)	(0.12)	(0.16)	(0.32)	(0.16)	(0.12)	(0.17)	(0.34	(0.17)
SO	6.17	9.91	1.11	1.45	2.01	1.59	1.61	2.08	3.91	2.31
	(0.61)	(0.65)	(0.10)	(0.14)	(0.25)	(0.14)	(0.10)	(0.14)	(0.29)	(0.14)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Table 4.4: Effects of Whole Tree and Stem Only Removal Treatments on Total Substrate Utilisation by the Soil Microbial Community

	S120	S240	S120 AA	S120 CARB	S120 CHO	S120 NP	S240 AA	S240 CARB	S240 CHO	S240 NP
SUMMER 2002										
WT	4.84	9.16	0.95	1.20	1.46	1.23	1.42	1.89	3.63	2.21
	(0.29)	(0.38)	(0.04)	(0.09)	(0.12)	(0.07)	(0.05)	(0.09)	(0.17)	(0.10)
SO	5.12	9.22	1.01	1.25	1.60	1.24	1.42	1.82	3.76	2.21
	(0.29)	(0.41)	(0.04)	(0.08)	(0.12)	(0.07)	(0.06)	(0.09)	(0.19)	(0.09)
SUMMER 2003										
WT	2.90	6.00 **a**	0.63	0.65	0.90	0.73 **a**	1.10 **a**	1.26 **a**	2.20	1.45 **a**
	(0.40)	(0.34)	(0.06)	(0.10)	(0.15)	(0.09)	(0.06)	(0.08)	(0.14)	(0.07)
SO	3.24	6.57 **b**	0.65	0.76	0.98	0.85 **b**	1.19 **b**	1.37 **b**	2.35	1.66 **b**
	(0.38)	(0.34)	(0.06)	(0.10)	(0.15)	(0.09)	(0.05)	(0.08)	(0.15)	(0.08)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Effects of Whole Tree and Stem Only Organic Matter Removal on the FH Litter Microbial Communities

As shown in Table 4.3, the total substrate utilisation by the FH litter microbial communities in the Biolog plates was not significantly influenced by the differences between the WT and SO organic matter removal treatment plots in either 2002 or 2003, and there was also no effect in any of the four substrate groups (S. App. 4.2.1 and 4.2.2). No trends were evident in the data, and there were no statistically significant fertilisation: organic matter removal interaction terms.

Effects of Whole Tree and Stem Only Organic Matter Removal on the Soil Microbial Communities

There were no differences in total utilisation by the soil microbial communities sampled from the WT and SO treatment plots in 2002, but in 2003 a number of significant differences between the two organic matter removal treatments were calculated in the utilisation data (Table 4.4). The total utilisation of nitrogen and phosphorous sources by the soil microbial community sampled from the SO treatment plots was greater than that of the WT treatment plots after 120 hours incubation, and after 240 hours incubation, the utilisation of all 31 substrates and all of the substrate groups, with the exception of the carbohydrates, was significantly greater by the SO treatment plot soil microbial communities (S. App. 4.2.1 and 4.2.2).

Only one significant fertilisation: organic matter removal interaction terms was detected in the analysis of the total substrate utilisation data. The utilisation of the amino acid substrate group by the soil microbial community in 2003 in the unfertilised WT and SO treatment plots was not different, but the utilisation by the fertilised WT plot community was significantly less than the SO plot community (S. App. 4.2.2).

Table 4.5: Effects of Organic Matter Removal Treatments on Total Substrate Utilisation by the FH Litter Microbial Community at Golden Downs, Kinleith, Tarawera and Woodhill combined

	F120	F240	F120 AA	F120 CARB	F120 CHO	F120 NP	F240 AA	F240 CARB	F240 CHO	F240 NP
SUMMER 2002										
FF	6.61	13.28	1.21	1.67	2.02	1.71	2.14	2.62	5.37	3.15 **a**
	(0.42)	(0.87)	(0.07)	(0.13)	(0.14)	(0.11)	(0.14)	(0.19)	(0.36)	(0.21)
WT	7.54	14.75	1.43	1.92	2.21	1.98	2.40	2.93	5.88	3.54 **b**
	(0.53)	(0.86)	(0.09)	(0.14)	(0.19)	(0.13)	(0.14)	(0.21)	(0.33)	(0.20)
SO	7.12	14.34	1.35	1.76	2.07	1.95	2.26	2.83	5.68	3.57 **b**
	(0.37)	(0.76)	(0.07)	(0.09)	(0.15)	(0.10)	(0.12)	(0.15)	(0.34)	(0.20)
SUMMER 2003										
FF	3.73 **a**	7.80 **a**	0.76 **a**	0.97 **a**	1.00 **a**	1.00 **a**	1.31	1.66 **a**	2.96 **a**	1.86 **a**
	(0.28)	(0.50)	(0.05)	(0.10)	(0.08)	(0.08)	(0.06)	(0.12)	(0.24)	(0.17)
WT	4.10 **a**	8.67 **b**	0.82 **a b**	1.11 **a b**	1.07 **a**	1.09 **a**	1.46	1.85 **a b**	3.30 **a b**	2.06 **b**
	(0.30)	(0.62)	(0.06)	(0.10)	(0.08)	(0.08)	(0.08)	(0.14)	(0.28)	(0.15)
SO	4.83 **b**	9.02 **b**	0.94 **b**	1.24 **b**	1.34 **b**	1.31 **b**	1.44	1.94 **b**	3.48 **b**	2.16 **b**
	(0.33)	(0.63)	(0.07)	(0.10)	(0.09)	(0.08)	(0.09)	(0.14)	(0.29)	(0.14)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Table 4.6: Effects of Organic Matter Removal Treatments on Total Substrate Utilisation by the Soil Microbial Community at Golden Downs, Kinleith, Tarawera and Woodhill combined

	S120	S240	S120 AA	S120 CARB	S120 CHO	S120 NP	S240 AA	S240 CARB	S240 CHO	S240 NP
SUMMER 2002										
FF	4.87	8.89	0.91	1.19	1.57	1.20	1.37	1.79	3.66	2.08
	(0.30)	(0.39)	(0.04)	(0.08)	(0.14)	(0.07)	(0.06)	(0.08)	(0.19)	(0.09)
WT	4.96	9.35	0.96	1.22	1.51	1.27	1.44	1.97	3.63	2.31
	(0.38)	(0.55)	(0.04)	(0.10)	(0.16)	(0.09)	(0.06)	(0.13)	(0.24)	(0.14)
SO	5.35	9.56	1.03	1.29	1.72	1.27	1.49	1.90	3.87	2.30
	(0.37)	(0.58)	(0.05)	(0.10)	(0.16)	(0.09)	(0.08)	(0.12)	(0.27)	(0.14)
SUMMER 2003										
FF	1.97 **a b**	5.31 **a**	0.53	0.48 **a b**	0.48 **a b**	0.48 **a**	0.95 **a**	1.15 **a**	1.92	1.29 **a**
	(0.20)	(0.27)	(0.04)	(0.06)	(0.05)	(0.05)	(0.04)	(0.07)	(0.13)	(0.07)
WT	1.86 **a**	5.22 **a**	0.50	0.41 **a**	0.46 **a**	0.49 **a**	0.98 **a**	1.12 **a**	1.82	1.31 **a**
	(0.20)	(0.20)	(0.04)	(0.06)	(0.05)	(0.05)	(0.03)	(0.05)	(0.10)	(0.05)
SO	2.31 **b**	6.11 **b**	0.54	0.56 **b**	0.60 **b**	0.62 **b**	1.09 **b**	1.29 **b**	2.13	1.61 **b**
	(0.23)	(0.35)	(0.05)	(0.08)	(0.07)	(0.05)	(0.04)	(0.09)	(0.16)	(0.09)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Effects of Organic Matter Removal on the FH Litter Microbial Communities

The analysis of substrate utilisation by the FH litter microbial communities at the four sites with all three organic matter removal treatments identified a substantial number of significant differences between the treatment plots (Table 4.5), and the majority of these were in summer 2003. Utilisation by the FH litter microbial communities collected from the FF treatment plots was significantly less than that of the communities sampled from the SO treatment plots, and in a number of cases there were also statistically significant differences in total utilisation between the FF and WT or WT and SO treatment plots as well (S. App. 4.3.2). The only significant effect of organic matter removal in 2002 was in the utilisation of nitrogen and phosphorous sources after 240 hours incubation, as the total utilisation by the FF treatment plot FH litter microbial communities was statistically lower (S. App. 4.3.1).

Several significant fertilisation: organic matter removal interaction terms were detected in the analysis of the 2003 substrate utilisation data for Golden Downs, Kinleith, Tarawera and Woodhill combined. Utilisation of all substrates and the four substrate groups by the FH litter microbial community after 120 hours incubation in 2003 was the same in the unfertilised WT and SO plots, but utilisation by the communities sampled from the WT fertilised plots was significantly lower than that from the fertilised SO treatment plots (S. App. 4.3.2).

The patterns of substrate utilisation by the FH litter microbial communities at the individual sites were substantially influenced by the different organic matter treatments. Statistical differences in the utilisation patterns of the substrates were found most consistently at Kinleith and Golden Downs, although significant effects were found at all six LTSP sites (S. App. 3.2 – 3.7). The nature of the differences between the treatments varied with site, as at Golden Downs in 2003 the utilisation patterns of the FH litter microbial communities sampled from the SO treatment plots were statistically different to both FF and WT treatment plots (Figure 4.14), but at Woodhill the statistical differences were between the FF and WT treatment plots (Figure 4.15).

Figure 4.14: Utilisation by Golden Downs FH Litter Microbial Community after 120 Hours Incubation – Summer 2003

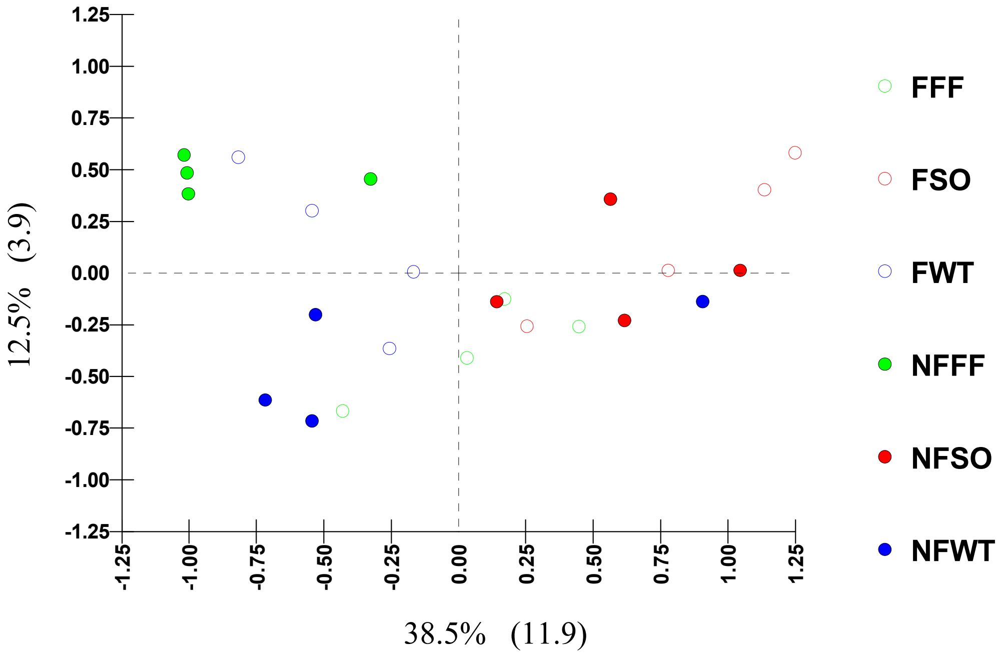
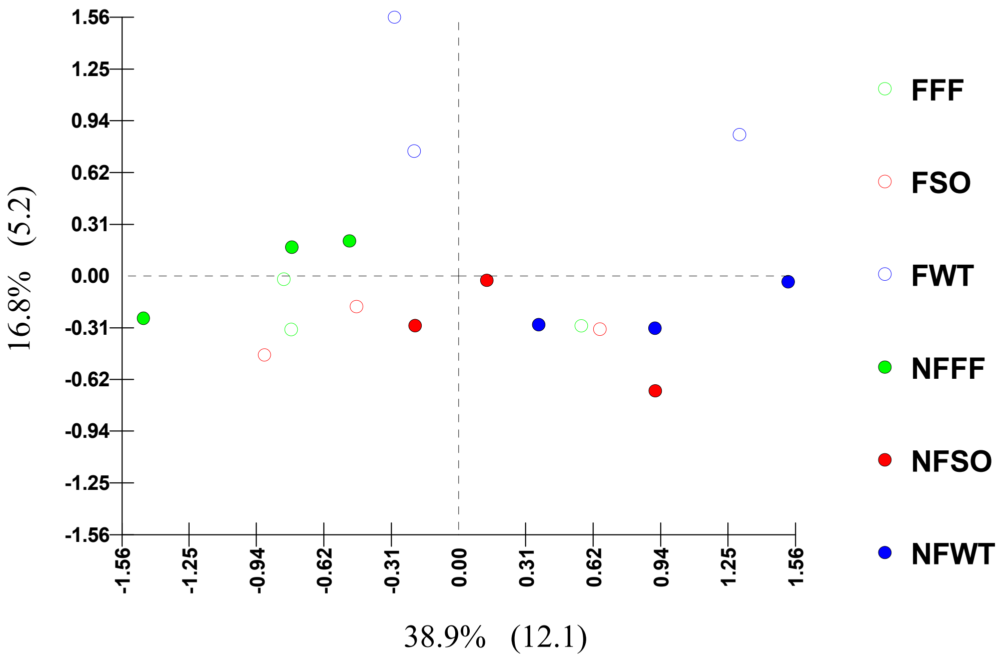


Figure 4.15: Utilisation by Woodhill FH Litter Microbial Community after 240 Hours Incubation – Summer 2003



Of the four substrate groups, the utilisation of amino acids tended to be the most influenced by the different levels of organic matter removal, and the utilisation of carboxylic acids was least likely to be significantly influenced by organic matter removal (S. App. 3.2 – 3.7).

Effects of Organic Matter Removal on the Soil Microbial Communities

The three organic matter removal treatments induced fewer differences in the total utilisation of the substrates by the soil microbial communities (Table 4.6) than the FH litter microbial communities, but there were still a substantial number of significant differences between the organic matter removal treatment plots in 2003 (S. App. 4.3.2). After 120 hours incubation, total utilisation in the Biolog plates by the SO treatment plot soil microbial communities was statistically greater than that of the WT treatment plots communities, and after 240 hours incubation the SO treatment plot soil microbial communities utilised more of the substrates than both the WT and FF treatment plot communities.

Statistically significant fertilisation: organic matter removal interaction terms were calculated in the utilisation of the carboxylic acids and nitrogen and phosphorous sources by the soil microbial community after 120 hours incubation in 2003. In both cases, utilisation was the same by microbial communities sampled from unfertilised WT and SO treatment plots, but the mean utilisation by the fertilised WT treatment plot community was less than the utilisation of the fertilised SO community (S. App. 4.3.2).

The patterns of substrate utilisation of the soil microbial communities sampled from the Woodhill, Tarawera and Kinleith sites differed statistically between the organic matter removal treatment plots in a number of cases (S. App. 3.2, 3.3 and 3.6). A single significant difference was found at Burnham (S. App. 3.5), but no effects of organic matter removal on the utilisation patterns of the soil microbial community were found at Berwick or Golden Downs. There was variation in the nature of the differences between the treatments at the sites, as it was identified that the SO treatment plots tended to be distinct from both FF and WT treatment plots at Woodhill (Figure 4.16), the FF treatment plots tended to be different to the SO plots at Tarawera, and the SO plots were distinct from the WT plots at Kinleith (Figure 4.17).

Figure 4.16: Utilisation by Woodhill Soil Microbial Community after 240 Hours Incubation – Summer 2003

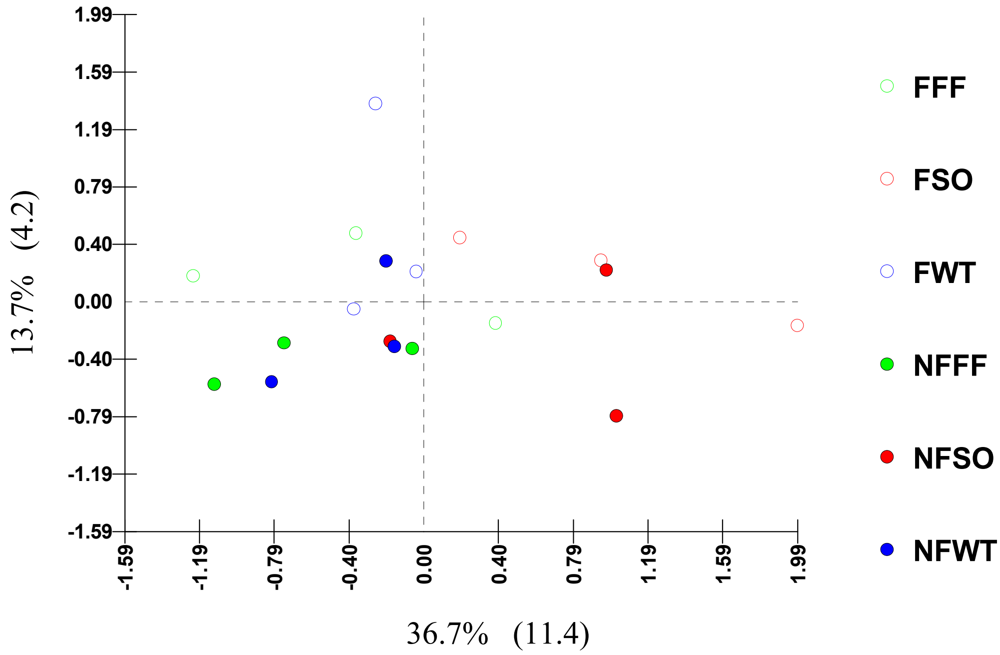
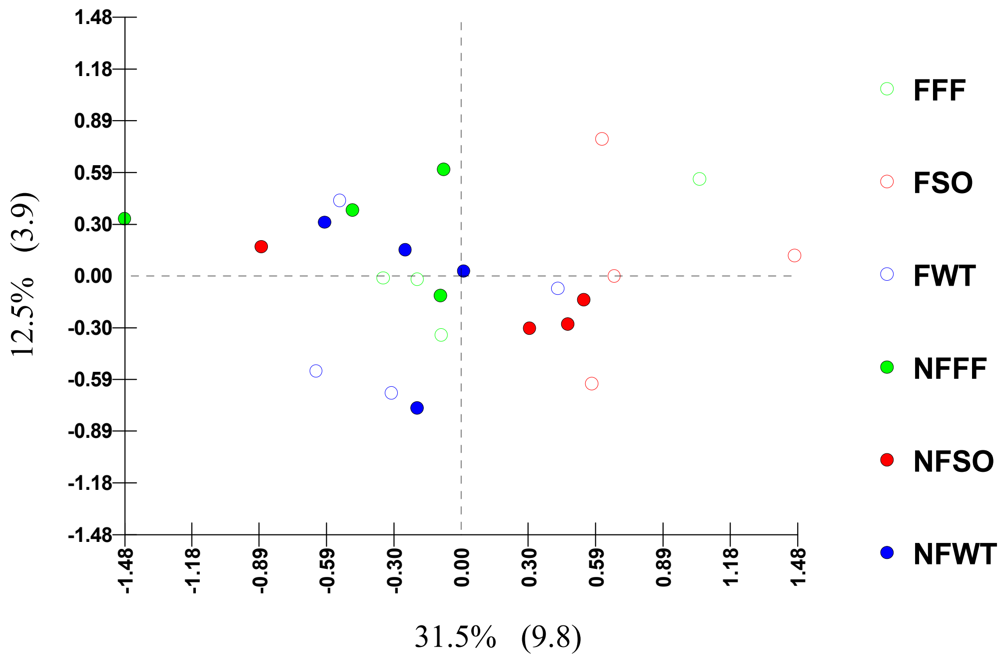


Figure 4.17: Utilisation by Kinleith Soil Microbial Community after 240 Hours Incubation – Summer 2003



There was no conclusive evidence to suggest that the utilisation of any of the four substrate groups by the soil microbial community was more readily influenced by the organic matter removal treatment than any other group.

4.3.4: FH Litter Microbial Substrate Utilisation Linear Regressions

Table 4.7 Relationships between Parameters and FH Litter Microbial Community Total Substrate Utilisation in Summer 2002

Substrates	R^2	p Value	FH Litter Microbial Biomass Parameters	Individual r^2	Coefficients	Intercept
F120	0.49	0.000	FH Moisture	0.20	11.93	9.77
			FH Biomass	0.20	0.02	
			Soil pH	0.9	-2.36	
F120 AA	0.43	0.000	FH Moisture	0.16	1.91	2.45
			Soil pH	0.14	-0.51	
			FH Biomass	0.13	0.003	
F120 CARB	0.46	0.000	FH Moisture	0.18	3.04	2.86
			FH Biomass	0.17	0.01	
			Soil pH	0.11	-0.68	
F120 CHO	0.46	0.000	FH Biomass	0.18	0.01	3.04
			FH Moisture	0.17	3.70	
			Soil pH	0.08	-0.73	
			FH Mass N	0.01	-5.00	
F120 NP	0.50	0.000	FH Moisture	0.23	3.09	2.20
			FH Biomass	0.19	0.01	
			Soil pH	0.08	-0.53	
F240	0.70	0.000	FH Moisture	0.50	25.49	17.57
			Soil pH	0.13	-3.79	
			FH Mass N	0.04	-28.18	
			FH Biomass	0.03	0.01	
F240 AA	0.68	0.000	FH Moisture	0.56	4.48	1.79
			Soil pH	0.06	-0.46	
			FH Biomass	0.03	0.002	
			FH Mass C	0.03	-0.11	
F240 CARB	0.53	0.000	FH Moisture	0.47	5.23	2.31
			Soil pH	0.04	-0.49	
			FH Mass N	0.02	-4.70	
F240 CHO	0.66	0.000	FH Moisture	0.35	9.39	10.19
			Soil pH	0.20	-2.06	
			FH Biomass	0.06	0.01	
			FH Mass N	0.05	-14.57	
F240 NP	0.68	0.000	FH Moisture	0.54	6.17	3.29
			Soil pH	0.07	-0.65	
			FH Mass N	0.07	-7.86	

Table 4.8 Relationships between Parameters and FH Litter Microbial Community Total Substrate Utilisation in Summer 2003

Substrates	R^2	p Value	FH Litter Microbial Biomass			
			Parameters	Individual r^2	Coefficients	Intercept
F120	0.65	0.000	FH Moisture	0.29	13.29	-0.44
			FH Mass C	0.20	7.88	
			FH Mass N	0.16	-267.40	
F120 AA	0.57	0.000	FH Moisture	0.32	2.10	0.11
			FH Mass C	0.14	1.03	
			FH Mass N	0.11	-34.73	
F120 CARB	0.65	0.000	FH Mass C	0.24	1.50	-0.09
			FH Moisture	0.20	2.47	
			FH Mass N	0.19	-50.24	
			Soil Moisture	0.02	1.68	
F120 CHO	0.61	0.000	FH Mass C	0.23	3.75	-0.52
			FH Moisture	0.20	4.91	
			FH Mass N	0.18	-128.52	
F120 NP	0.68	0.000	FH Moisture	0.34	3.12	0.03
			FH Mass C	0.18	1.68	
			FH Mass N	0.16	-57.12	
F240	0.69	0.000	FH Moisture	0.48	13.67	6.39
			Soil Moisture	0.13	13.69	
			FH % N	0.08	-3.71	
F240 AA	0.57	0.000	FH Moisture	0.53	3.44	0.47
			FH Biomass	0.04	-0.003	
F240 CARB	0.67	0.000	FH Moisture	0.62	3.32	0.42
			Soil Moisture	0.05	1.82	
F240 CHO	0.67	0.000	FH Moisture	0.36	5.26	2.74
			Soil Moisture	0.19	7.27	
			FH Mass N	0.12	-1.90	
F240 NP	0.68	0.000	FH Moisture	0.48	2.97	1.47
			Soil Moisture	0.13	2.97	
			FH Mass N	0.7	-0.75	

A substantial degree of variation in the total utilisation of the substrates by the FH litter microbial community was explained in the regression models described in Tables 4.7 and 4.8, as the R^2 values for the various substrate groups ranged from 0.43 to 0.70. The models generated from the summer 2002 after 120 hours incubation explained the least degree of variation, but there was no real difference in the R^2 values for the regression models from the other combinations of year and incubation time.

The parameter most related to total substrate utilisation by the FH litter microbial community in the summer 2002 and 2003 sampling rounds was FH moisture, which was positively correlated to substrate utilisation in every case, and was statistically the most important component in the regression models with only two exceptions (Tables 4.7 and 4.8). In summer 2002, the FH biomass parameter, representing the mass of NH_4-N extracted from the microbial tissue, was positively related to total substrate utilisation after 120 hours incubation and explained a substantial degree of variation, and the soil pH parameter also was found to be a significant component of the regression models in summer 2002, and was uniformly negatively correlated to total substrate utilisation (Table 4.7).

The total masses of carbon and nitrogen contained in the FH litter layer were found to be important predictors of substrate utilisation by the FH litter microbial communities after 120 hours incubation in summer 2003, and were positively and negatively related to utilisation respectively, although FH Mass N was also a significant component of the carbohydrate and nitrogen and phosphorous source utilisation regression models after 240 hours incubation. The soil moisture parameter was also an important component of the summer 2003 regression models, and was positively related to total utilisation (Table 4.8).

4.3.5: Soil Microbial Substrate Utilisation Linear Regressions

Table 4.9 Relationships between Parameters and Soil Microbial Community Total Substrate Utilisation in Summer 2002

Substrates	Soil Microbial Biomass					
	R^2	p Value	Parameters	Individual r^2	Coefficients	Intercept
S120	0.66	0.000	Soil % C	0.33	0.36	2.71
			FH Biomass	0.23	0.01	
			Soil % N	0.10	-4.96	
S120 AA	0.36	0.000	FH Biomass	0.19	0.001	0.68
			Soil % C	0.10	0.01	
			Soil Biomass	0.07	0.01	
S120 CARB	0.44	0.000	Soil % C	0.21	0.08	0.70
			FH Biomass	0.17	0.003	
			Soil % N	0.06	-1.20	
S120 CHO	0.78	0.000	Soil % C	0.21	0.11	0.72
			FH Biomass	0.19	0.004	
			FH % C	0.16	0.03	
			FH Moisture	0.14	-1.51	
			Soil % N	0.08	-1.72	
S120 NP	0.61	0.000	Soil % C	0.35	0.08	0.71
			FH Biomass	0.18	0.002	
			Soil % N	0.08	-1.06	
S240	0.72	0.000	Soil Moisture	0.64	20.27	8.64
			FH Moisture	0.08	-8.30	
S240 AA	0.63	0.000	Soil Moisture	0.48	2.82	1.08
			FH Moisture	0.07	-1.14	
			FH Biomass	0.04	0.001	
			FH Mass	0.04	0.04	
S240 CARB	0.57	0.000	Soil Moisture	0.46	4.67	1.66
			FH Moisture	0.09	-2.02	
			FH Mass	0.02	0.04	
S240 CHO	0.73	0.000	Soil Moisture	0.64	9.31	3.63
			FH Moisture	0.09	-4.09	
S240 NP	0.66	0.000	Soil Moisture	0.57	5.09	1.69
			FH Moisture	0.06	-1.70	
			FH Mass	0.03	0.04	

Table 4.10 Relationships between Parameters and Soil Microbial Community Total Substrate Utilisation in Summer 2003

Substrates	R^2	p Value	Soil Microbial Biomass			
			Parameters	Individual r^2	Coefficients	Intercept
S120	0.61	0.000	FH Moisture	0.34	8.05	-0.15
			FH Mass	0.13	1.88	
			FH Mass N	0.11	-137.92	
			Soil Biomass	0.03	-0.02	
S120 AA	0.58	0.000	FH Moisture	0.39	1.51	0.10
			FH Mass	0.09	0.21	
			FH Mass N	0.07	-14.93	
			Soil Moisture	0.03	-0.76	
S120 CARB	0.55	0.000	FH Moisture	0.50	2.28	0.56
			FH % N	0.04	-0.55	
			Soil Biomass	0.01	-0.01	
S120 CHO	0.58	0.000	FH Moisture	0.27	2.81	-0.18
			FH Mass	0.16	0.79	
			FH Mass N	0.13	-58.23	
			Soil Biomass	0.02	-0.01	
S120 NP	0.61	0.000	FH Moisture	0.31	1.85	-0.01
			FH Mass	0.16	0.49	
			FH Mass N	0.13	-35.67	
			Soil Biomass	0.01	-0.01	
S240	0.63	0.000	Soil Moisture	0.40	13.22	5.95
			Soil Biomass	0.10	-0.03	
			FH % N	0.08	-2.03	
			FH Moisture	0.05	2.60	
S240 AA	0.50	0.000	FH Mass C	0.20	0.46	0.61
			Soil Moisture	0.12	1.11	
			FH Mass N	0.12	-13.72	
			FH Moisture	0.06	0.50	
S240 CARB	0.59	0.000	Soil Moisture	0.37	2.65	0.35
			FH % N	0.08	-0.42	
			FH Moisture	0.08	0.69	
			Soil Biomass	0.03	-0.01	
			FH % C	0.03	0.02	
S240 CHO	0.64	0.000	Soil Moisture	0.33	5.67	2.35
			Soil Biomass	0.19	-0.02	
			FH % N	0.08	-0.91	
			FH Moisture	0.04	1.11	
S240 NP	0.63	0.000	Soil Moisture	0.55	3.50	1.41
			FH % N	0.04	-0.45	
			FH Mass C	0.02	0.13	
			Soil Biomass	0.02	-0.01	

The variation explained by the regression models describing total substrate utilisation by the soil microbial communities in summer was generally substantial, and did not differ greatly with year (Tables 4.9 and 4.10). However, the degree of variation explained by the regression models for the different substrate groups in summer 2002 did vary somewhat, as the variation in utilisation of the amino acids and carboxylic acids was much lower than the variation in the utilisation of the carbohydrates (Table 4.9).

The parameters that were most important to the utilisation regression models in summer 2002 varied with the time of incubation. The percentage of carbon in the soil was the parameter most related to the models after 120 hours incubation, and was positively correlated to substrate utilisation. Soil moisture was the most important parameter after 240 hours incubation, and was also positively correlated to substrate utilisation by the soil microbial communities in the Biolog plates (Table 4.10).

The parameters that were important to the summer 2003 regression models of utilisation by the soil microbial communities also varied substantially with time of incubation. FH moisture was the most important parameter in the regression models after 120 hours incubation, and was positively correlated to utilisation. The total FH litter mass and the mass of nitrogen in the FH litter of the forest floor were also calculated to be consistently related to substrate utilisation by the soil microbial community after 120 hours, but were not related to the utilisation of carboxylic acids (Table 4.10). After 240 hours incubation, the soil moisture parameter was positively correlated to substrate utilisation, and explained the greatest degree of variation in utilisation in all cases with the exception of amino acids, the utilisation of which was best explained by the mass of carbon in the FH litter on the forest floor (Table 4.10).

4.4: DISCUSSION

Before addressing the results produced with the Biolog plates, several issues regarding the utilisation of the plates in general and specifically in this study require examination. As mentioned previously in Section 4.2, Biolog plates do not produce direct measurements of microbial community diversity, but instead measure the catabolic diversity of the community, which is then used as a relative measure of microbial species diversity (Zak *et al*., 1994). This does not provide specific information regarding the species that were present in the community at the time of sampling, and without modification to the plates, is limited only to the bacterial component of the microbial community. However, as the aims of this study did not involve identifying and tracking changes in the relative diversity of particular microbial species, Biolog plates were considered appropriate to examine the relative differences in diversity between the sites and levels of the fertilisation and organic matter removal treatments.

The substrate utilisation results were not considered to be definitive measurements of the catabolic diversity of the microbial communities in the actual sites, only in the environment of the Biolog plates. Although the patterns of utilisation indicated that there were many substantial differences in the diversity of the microbial communities between the sites and treatment plots, this could not be considered as conclusive proof that the catabolic diversity of these communities in the actual sites was different. This was due to the unknown impact of non-culturable species that were present and active in the forest ecosystem, but not in the Biolog plates (Perfilev and Gabe, 1969; Bakken, 1985; Tunlid and White, 1992). Additionally, in a comprehensive review of the use of Biolog plates, Preston-Mafham *et al*. (2002) suggested that the catabolic response of the various microbial species may be differentially influenced by the conditions in the plates, skewing utilisation patterns and further complicating comparisons of utilisation patterns under laboratory conditions and in the field. Consequently, the substrate utilisation patterns cannot be considered as unqualified predictors of the catabolic capability of the microbial communities, but they can be used as a relative yardstick of what the microbial communities utilise when presented with the same substrates under the same conditions (Preston-Mafham *et al*., 2002), although it has been suggested that with the use of more advanced Biolog plates and analytical techniques, substrate utilisation patterns can be indicative of microbial activity in the forest ecosystem (Grayston and Prescott, 2005).

Another issue regarding the utilisation of Biolog plates was how the Biolog method separates sites and treatments based on utilisation patterns when compared to other methods of assessing microbial community diversity. Widmer *et al*. (2001), comparing Biolog, DNA and PLFA based methods of assessing microbial community diversity in three soils, found that all methods were able to distinguish the differences between the soil, but the nature of the differences varied with the method used. Consequently, it was recommended that multiple methods for assessing diversity be used, and the results compared to more accurately identify any variations in diversity (Widmer *et al*., 2001). A limited trial to test the effectiveness of PLFA profiles was conducted with some of the soil samples collected from the LTSP sites in summer 2002, and a description of the trial and the results are given in Appendix Five. As with the study of Widmer *et al*. (2001), the PLFA trial identified significant differences in the diversity of the microbial community across the LTSP sites, but the relative differences between the sites varied substantially when compared with those identified by the Biolog method. (Refer Figures 4.4, 4.5 and A.1). However, due to time constraints, further PLFA analyses were not carried out in the later sampling rounds, and the degree of variation in the results of the different methods at other times was left unknown.

With regard to the conditions of incubation, the majority of Biolog experiments have used incubation temperatures between 15 and 28^{o}C (Preston-Mafham *et al*., 2002). The temperature used in this study was 12^{o}C, colder than in most previous studies. The rationale behind this decision was based on attempting to replicate the average temperatures across all sites in summer and winter, which was calculated to be 12.2^{o}C (refer Appendix Two), as it was hypothesised that a higher temperature may have selected for species not normally prominent in the microbial community at lower temperatures.

In the literature, the length of time between plate readings tends to decrease with increasing temperature of incubation, and the combination of plate readings every 12 hours at 25°C incubation is often used (Zak *et al*., 1994; Dhillion *et al*., 1996; Li *et al*., 2004). To determine the appropriate length of time interval between plate readings with incubation at 12°C, a trial was conducted to determine the most appropriate timing and frequency of measurements of utilisation in the Biolog plates. From this, it was concluded that measurements of utilisation after 120 hours and 240 hours incubation yielded satisfactory results, as patterns of utilisation were becoming apparent after 120 hours, and by comparison to the readings after 120 hours, utilisation of the substrates was not close to reaching an end point, indicating that the data produced by the plate reading after 240 hours would also produce useful results.

4.4.1: Spatial Variations in FH Litter and Soil Microbial Community Substrate Utilisation

FH Litter Microbial Community Substrate Utilisation

There were significant differences in the substrate utilisation patterns of the FH litter microbial communities sampled from the different LTSP sites (Figures 4.2 – 4.5), which were interpreted to be indicative of significant differences in the microbial community species diversity at the sites, according to the issues discussed previously in Section 4.4. Significant differences in substrate utilisation by the FH litter microbial community sampled from different forest sites have been reported previously, although the F and H litter layers were analysed separately (Grayston and Prescott, 2005).

The site parameter that was found to be most responsible for the differences between the LTSP sites was the amount of moisture in the FH litter. This parameter varied with site and year (Section 2.3.1 – 2.3.6), and this variation was reflected in the patterns of utilisation shown in Figures 4.2 – 4.5, as sites with drier FH litter tended to be situated to the left of the principal axis, and sites with more moisture in the FH litter were on the right. This difference was more distinct after 240 hours incubation, and in 2003 when there was less rainfall and the FH litter at most sites was drier (refer Appendix One). It was also noted that the degree of variation in substrate utilisation explained by the principal axis was also greatly increased in 2003 (Figures 4.4 and 4.5), suggesting that the drier conditions in the FH litter in 2003 made moisture a more critical factor to the diversity of the FH litter microbial community, reducing the variability in diversity associated with other environmental factors, and consequently in the PCA. These conclusions were supported by statistical analysis, as the r^2 values of the correlation between the FH litter moisture content and the relative positions of the individual treatment plots on the principal axis in 2002 were 0.25 and 0.61 after 120 and 240 hours respectively, and 0.42 and 0.63 after 120 and 240 hours respectively in 2003 (S. App. 3.8.1).

Soil Microbial Community Substrate Utilisation

Based on the statistical analysis of relative positions of the data points on the principal axis in Figures 4.6 – 4.9, there were several significant differences in the substrate utilisation patterns, and consequently diversity, of the soil microbial communities at the six LTSP sites. Site-based differences in substrate utilisation patterns have been reported previously in forest ecosystems, and the differences between the sites were considered to be due to variations in the soil properties at the different sites (Li *et al*., 2004).

In this study, the relative statistical differences in microbial diversity between the sites were found to vary with year and the length of incubation of the Biolog plates, and the parameters that were most closely related to the relative positions of the data points on the principal axis also varied. After 120 hours incubation in 2002 (Figure 4.6), the relative positions of the sites were related to the percentage of carbon in the soil ($r^2 = 0.50$), as the sites with the less carbon were on the left of the axis, and sites with a greater soil carbon percentage were on the right. After 120 hours incubation in 2003, the FH moisture parameter was the best predictor of the relative positions of the individual treatment plots on the principal axis ($r^2 = 0.40$), with drier sites on the left of the axis and wetter sites on the right (Figure 4.8). As the soil carbon parameter was not measured in 2003, it was not known if this parameter was significantly related to substrate utilisation patterns in 2003.

After 240 hours incubation in both 2002 and 2003, the percentage of moisture in the soil was the most accurate predictor of substrate utilisation patterns by the soil microbial community. The proportion of variation explained by the parameter in 2002 was 0.68, and was 0.45 in 2003 (S. App. 3.8.2). Although the percentage of carbon in the soil was an important factor after 120 hours incubation, it was concluded that the availability of moisture was the most critical factor in determining the relative diversity of the soil microbial communities at the different LTSP sites, as a clear gradient was established along the principal axis of the PCA plots, with wetter sites to the left, and drier sites to the right.

4.4.2: Effects of Fertilisation and Organic Matter Removal Treatments on FH Litter Microbial Community Substrate Utilisation

Fertilisation Treatment

Significant effects of fertilisation were not detected in the total substrate utilisation figures for the LTSP plots in 2002, but in 2003 substrate utilisation in the fertilised treatment plots was significantly greater in general, and the utilisation of the amino acid and carboxylic acid substrate groups in particular was greater (Table 4.1). Comparative statistics regarding the effects of fertilisation on total substrate utilisation by FH microbial communities were not available in the literature, so the significant trends identified in these results cannot be compared to other findings.

Organic Matter Removal Treatments

There were no significant differences between the total substrate utilisation of the FH litter microbial communities sampled from the WT and SO treatment plots in either 2002 or 2003, but several significant differences were found in 2003 when the data from the sites with all three level of organic matter removal were analysed (Table 4.5). Utilisation was significantly lower in plots with increased levels of organic matter removal, and this trend was observed after both incubations times, and in all substrate groups. As comparative data from other studies could not be found, these results could not be verified against other research.

Relationships between Treatment Effects, Environmental Conditions and FH Litter Microbial Community Diversity

The basis for the differences in total substrate utilisation by the FH litter microbial communities resulting from fertilisation and organic matter removal treatments were examined in terms of the effects of treatments on the parameters of the environment that were calculated to be statistically related to total substrate utilisation (Tables 4.7 and 4.8). In both 2002 and 2003, FH litter moisture tended to be increased by fertilisation and decreased by organic matter removal (refer Tables 2.10 and 2.12), was the most important parameter in the substrate utilisation regression models, and was uniformly positively correlated with substrate utilisation. The degree of variation in substrate utilisation explained by the FH litter moisture was reasonably high, although it was noted the r^2 values after 120 hours incubation in 2002 were substantially lower. Consequently, it was suggested that the influence of the treatments on FH litter moisture was the main mechanism by which the treatments statistically influenced total substrate utilisation in 2003, as total utilisation and FH moisture were statistically related, both were increased by fertilisation, and both were decreased by increasing levels of organic matter removal.

It must be noted, however, that the effects of fertilisation and organic matter removal on FH litter moisture were not statistically significant across all sites combined in 2003, although the differences were significant at several of the individual sites. Additionally, in 2002, when there were no strong effects of either the fertilisation or organic matter removal treatments on total substrate utilisation by the FH litter microbial communities, the effects of the treatments on FH litter moisture were significant across all sites. It was hypothesised that this phenomenon was related to the increased availability of moisture in summer 2002 (Appendix One).

The relationship between moisture content and substrate utilisation by the FH litter microbial community in this study was supported to some extent by Grayston and Prescott (2005), who reported that the substrate utilisation by the FH litter microbial community differed across four sites, and the sites at which greatest utilisation tended to be found were also wetter. However, it must be noted that this potential relationship was not explicitly stated by

Grayston and Prescott (2005), the relationship was not investigated statistically, and there were also some differences in the methodology of this study.

Other parameters of the physical, chemical and biological environment were also statistically related to the total substrate utilisation of the FH litter microbial community at various times. The biomass of the FH litter microbial community, the mass of carbon in the FH litter and the soil moisture content of the soil were all positively related to total substrate utilisation by the FH litter microbial community, and soil pH was negatively related to total utilisation. It was determined that these parameters had all been influenced by the fertilisation and/or the organic matter removal treatments in such a ways as to produce the differences in total utilisation. The only exception was the parameter describing the mass of nitrogen in the FH litter, as this was negatively related to total substrate utilisation, but was increased by fertilisation, and decreased by increasing levels of organic matter removal.

This conclusion regarding substrate utilisation by the FH Litter microbial communities was supported by the statistical analysis of the effects of the treatments on the substrate utilisation patterns of the FH litter microbial community at the individual sites. Fertilisation significantly changed the relative diversity of the FH litter microbial communities at Berwick, Burnham and Kinleith in several instances (e.g. Figure 4.13), and there were significant differences in the relative diversity of the FH litter microbial communities sampled from the different organic matter removal treatment plots at all six LTSP sites (e.g. Figures 4.15 and 4.16).

Despite the discrepancy identified in relationship with the mass of nitrogen in the FH litter, it was concluded that the differences in the environmental parameters caused by the treatments could be considered as the factors responsible for the differences in total substrate utilisation by the FH litter microbial communities sampled from the different treatment plots. As the differences in utilisation were considered to represent the relative differences in the diversity of the microbial community, it was determined that there was sufficient evidence to suggest that the alterations to the environmental conditions resulting from the fertilisation and organic matter removal treatments influenced the selection pressures in the FH litter of the plots, resulting in the establishment of different microbial communities.

4.4.3: Effects of Fertilisation and Organic Matter Removal Treatments on Soil Microbial Community Substrate Utilisation

Fertilisation Treatment

Fertilisation did not significantly affect total substrate utilisation by the soil microbial communities sampled from the LTSP sites in either 2002 or 2003 (Table 4.2). These results do not agree with those of Sarathchandra *et al*. (2001), who reported that substrate utilisation by soil microbial communities sampled from unfertilised plots was greater than that of communities sampled from plots that received applications of nitrogenous fertiliser. However, Sarathchandra *et al*. (2001) used a different range of substrates to those employed in this study, and this may account for some of the discrepancy in these results.

Organic Matter Removal Treatments

No significant differences in total substrate utilisation at the LTSP sites were found between the different levels of the organic matter removal treatment in 2002, although total utilisation tended to be greater in plots with less organic matter removal (Tables 4.4 and 4.6). In 2003, these differences were calculated to be significant in many cases, particularly when the FF treatment was included (Table 4.6). Li *et al*. (2004) reported that there were a number of significant differences in the utilisation of individual Biolog substrates between soil communities sampled from WT and SO plots at two forested sites in North Carolina, but the differences in total utilisation were not significant. These results agree to some extent with those reported in this study, as there were no significant differences in total utilisation between the WT and SO treatment plots at the LTSP sites in 2002, but several were calculated in 2003, particularly in the utilisation of the nitrogen and phosphorous sources (Table 4.4).

Relationships between Treatment Effects, Environmental Conditions and Soil Microbial Community Diversity

As with the examination of the effects of the treatments on the FH litter microbial community, the significant differences in total substrate utilisation by the soil microbial communities were considered in terms of the statistical relationships between utilisation and the environmental conditions (Tables 4.9 and 4.10). The parameters that were most related to total substrate utilisation by the soil microbial communities varied with year and time of incubation, as did the degree of variation in utilisation explained by the parameters, but all were positively related to utilisation.

After 120 hours incubation, the percentage of carbon in the soil was the parameter most related to total substrate utilisation in 2002, although the degree of variation explained varied substantially across the substrate groups, and was not particularly high. The relationship between the percentage of carbon in the soil, total substrate utilisation and the effects of the organic matter removal treatments on both all agreed, as soil carbon content and total utilisation both tended to be decreased by increasing levels of organic matter removal in 2002 (Tables 2. 12 and 4.6). After 120 hours incubation in 2003, FH litter moisture content was the parameter most closely related to total substrate utilisation by the soil microbial community, and this also followed on from the effects of the organic matter removal treatment, as both FH litter moisture and substrate utilisation tended to be decreased by organic matter removal. It was hypothesised that the unavailability of the soil carbon content parameter in 2003 would reduce the degree of variation in substrate utilisation explained by the regression models, but the r^2 values of the FH moisture parameter in 2003 was either the same or better than the soil carbon content parameter in 2002, and there were no consistent differences between the overall models.

After 240 hours incubation, the soil moisture parameter was the most important component of the substrate utilisation models in 2002 and 2003, and explained a substantial degree of variation in substrate utilisation, particularly in 2003. Soil moisture in both 2002 and 2003 was decreased by increasing levels of organic matter removal, as was total substrate utilisation by the soil microbial community, and this information combines to suggest that the decreases in soil moisture were responsible for the decreases in total substrate utilisation.

In the literature, soil pH has been statistically related to substrate utilisation patterns of soil microbial communities in forest environments (White *et al*., 2005). Although the organic matter removal treatments were found to produce significant differences in soil pH at the LTSP sites (Table 2.12), there was no relationship between soil pH and total substrate utilisation by the soil microbial community in 2002 (Table 4.9). However, there was a relationship between the soil pH and total substrate utilisation for the FH litter microbial community (Table 4.7).

These conclusions regarding the potential of the organic matter removal treatments to influence substrate utilization by the soil microbial community were supported by the statistically significant effects of organic matter removal of the patterns of substrate utilisation of the soil microbial communities at the individual LTSP sites (e.g. Figures 4.15 and 4.16). Some sites were affected more than others by the treatment differences, but statistical differences were identified at every site.

Although fertilisation did not statistically influence the total substrate utilisation in either 2002 or 2003, fertilisation did influence the relative diversity of the soil microbial community at Tarawera (Figure 4.14), and also had some effects Woodhill, Berwick and Kinleith. However, the statistical relationship between these differences and the environmental parameters in the treatment plots was not determined, so the potential mechanism responsible for these differences was unknown.

A number of significant differences were found in the patterns of substrate utilisation by the soil microbial communities sampled from fertilised and unfertilised plots at Tarawera (S. App. 3.3). The utilisation patterns of the soil microbes sampled from Woodhill, Berwick and Kinleith were also influenced by the fertilisation treatment in several cases (S. App. 3.2, 3.4 and 3.6), although the utilisation patterns at Tarawera were most often affected by fertilisation (Figure 4.14). The utilisation patterns of soil microbial communities sampled from Burnham or Golden Downs were unaffected.

As a consequence of these results, it was determined that organic matter removal substantially influenced both total substrate utilisation and the substrate utilisation patterns of the soil microbial community, and the mechanism for this was due to the alterations in the environmental caused by organic matter removal. As the differences in utilisation were considered to be analogous to differences in the diversity of the microbial communities, it was concluded that the environmental differences caused by the organic matter removal treatments were altering the selection pressures on the soil microbial communities, resulting in measurable differences in the diversity of the communities. Fertilisation also produced measurable differences in the diversity of the soil microbial community at several sites, but the likely reasons for the differences was not determined.

4.4.4: Conclusions

Based on patterns of substrate utilisation, the structure of the FH litter and soil microbial communities at the individual LTSP sites were characterised, and a number of significant statistical differences in the relative diversity of the microbial communities at the sites were identified. This confirmed the first hypothesis, although it must be noted that the relative differences between the sites varied with year, potentially due to variation in climatic influences prior to sampling.

The structure of the FH litter and soil microbial communities in the LTSP sites were found to differ significantly between fertilised and unfertilised plots in several cases, but the lack of consistent differences across all of the sites requires that the second hypothesis of this chapter cannot be considered to be confirmed. The hypothesis does hold true for some sites, but at others, fertilisation did not produce measurable shifts in microbial community structure.

The third hypothesis was confirmed, however, as significant differences in FH litter and soil microbial community structure were identified consistently across all sites, although the differences between the different levels of the treatments were more pronounced in 2003.

Examination of the regression analyses concluded that substantial variation in the utilisation of the substrates could be related to parameters of the physical, chemical and biological environment within the treatment plots at the LTSP sites with a reasonable degree of confidence, confirming the last hypothesis of this chapter. Furthermore, these relationships could also be used to identify the most likely reasons for the statistical differences in substrate utilisation and diversity between the sites and treatment levels in the treatment plots.

Perhaps the best overall interpretation of these results is based on the consideration of the nature of microbial communities. The diversity of the microbial communities, like biomass, is not fixed, but is in a state of flux dictated by environmental factors (Leckie, 2005). In accordance with this concept, the results of this chapter indicate that the fertilisation and organic matter removal treatments have created an environment that results in differences between the communities, but only under certain broader conditions. One of these conditions appeared to be moisture availability, as in 2002 there were few significant differences between the communities based on treatment effects, although there were a number of non-significant trends, but in 2003 when moisture was more limited, the differences in diversity between the microbial communities in the different treatment plots was highly significant. This concept was supported by the differences between the sites, which followed a gradient of moisture availability, and were also more accurately modelled by PCA in 2003 when it was drier. Furthermore, it was also suggested that if water availability at the LTSP sites in later years was increased, the differences induced by the treatments would not be as critical, and the relative differences in microbial community diversity between the treatment plots and study sites would decrease.

It was also important to consider these results in light of the concept of functional redundancy with microbial communities. Two hypothetical microbial communities could be composed of quite different species, but if the catabolic capacity of the communities was the same, and both communities responded the same way to the conditions within the Biolog plates, theoretically no differences would be detected in total, or patterns of, substrate utilisation. Based on the results attained in this study, it was suggested that in the majority of cases, the differences between the sites and the effects of the treatments overrode whatever degree of functional redundancy that was present within the microbial communities at the LTSP sites, as numerous significant differences in the catabolic capabilities of the microbial communities were found. Lastly, the long-term nature of the effects of the treatments, particularly organic matter removal, requires consideration. Significant differences in the diversity of the microbial communities were produced by these treatments, up to 17 years after treatment application, further indicating the potential for this kind of disturbance to influence the microbial community.

CHAPTER FIVE: EFFECTS OF FERTILISATION AND ORGANIC MATTER REMOVAL ON *PINUS RADIATA* PRODUCTIVITY

5.1: INTRODUCTION

The potential for fertilisation regimes and site preparation practices to affect the physical and chemical properties of the forest floor environment is well known, as is the potential for alterations of these properties to influence the growth characteristics of forest stands (Archibold *et al*., 2000; Grigal 2000). There are numerous examples in the literature regarding the effects of nitrogenous fertilisation on the growth of various species of trees across a wide range of locations, and generally the addition of nitrogen has been reported to stimulate measurements of growth, particularly at sites with lower nitrogen availability (Kenney, 1980; Smith *et al*., 2000; Nohrstedt *et al*., 2001). A substantial amount of information is also available regarding the effects of increased levels of organic matter removal from harvested sites prior to the establishment of the next rotation of trees, and this had been found to decrease the productivity of the site during the next rotation, and may also impact on the growth of the trees during successive rotations (Ballard, 1978; Skinner *et al*., 1989; Proe and Dutch, 1994; Stone and Elioff, 1998; Stone and Kabzems, 2002).

Despite the fact that much is known regarding the impacts of various forest management practices on a number of parameters of forest productivity, substantially less is known about how the management practices may indirectly influence growth, by altering the structure and function of the microbial community in the litter layer and soil (Hooper *et al*., 2000; Wardle *et al*., 2001; Leckie, 2005). As previously discussed, microbes mediate a wide variety of processes that have the potential to influence the growth of trees, and it is of great interest to determine if alterations to the characteristics of the microbial community resulting from management practices or other disturbances can be accurately related to the productivity of the trees, independently of the direct effects, such as increased nutrient availability from fertilisation.

Another facet of plant productivity that can be influenced by management practices is the relative rate of litterfall from trees, and the nutritional characteristics of the litter (Smith *et al*., 2000). Addressing the affects of the fertilisation and organic matter removal treatments on the mass and nutrient content of the plant litter is important, as litterfall represents an important link between the trees and the forest floor in terms of nutrient flux (Olson, 1963), and also has the potential to influence the physical environment in the litter layer and soil as well.

The aim of the work reported in this chapter was to attempt to determine if the fertilisation and organic matter removal treatments had influenced the growth rates and litter production of the trees in the treatment plots, and if the characteristics of the microbial communities determined in the previous chapters could be accurately related to the productivity at the LTSP sites. To accomplish this, the following hypotheses were examined:

1. That fertilisation has significantly increased litterfall and litterfall nutrient content.
2. That increasing organic matter removal has significantly decreased litterfall and litterfall nutrient content, and has significantly decreased rates of tree growth.
3. That fertilisation has significantly increased rates of tree growth.
4. That increasing organic matter removal has significantly decreased rates of tree growth.
5. That any differences in tree growth in the different treatment plots could be statistically related to the characteristics of the FH litter and soil microbial communities.

5.2: METHODS AND MATERIALS

5.2.1: Litter Trap Construction and Installation

To make the nets for the 122 litter traps required, lengths of heavy-duty nylon shadecloth with a 1.5 mm mesh size were cut into squares 1.2 meters to a side. This type of shadecloth was used because the particular weave of the nylon fibres tended to catch and hold pine needles more readily than other materials, based on experimentation with a range of shadecloth and netting samples. Additionally, the gaps in the weave allowed for rapid drainage of water through the material, allowing the material in the traps to dry rapidly and reduce mass loss through decomposition and leaching. The breaking strain of the shadecloth was also high, and the materials in the shadecloth were advertised as degrading very slowly in the field. Four 0.6m wooden stakes were attached to the shadecloth squares, approximately 100mm in from the corners. The stakes were attached with several heavy-duty staples, and these were hammered into the stakes to reduce the chance of the shadecloth coming free.

The litter traps were initially installed in July and August 2002 at the Woodhill, Berwick, Burnham and Golden Downs sites, and litter traps were installed at the Tarawera and Kinleith sites during the summer 2003 sampling round. To install the litter traps, the stakes were pulled tight, although not completely, as it was determined that a large degree of concavity was required to ensure the retention of the litter. The stakes were partially hammered into the soil, and the relative position of the stakes was checked to ensure that the horizontal surface area of the shadecloth net was still approximately 1m^2. The stakes were then hammered deeper into the soil, until the clearance between the bottom of the shadecloth net and the surface of the forest floor was approximately 200mm.

The litter traps were placed approximately in the centre of each treatment plots, as it was hoped that this would reduce the chance of litter from adjacent treatment plots drifting into the litter traps. There was some variation in elevation in the treatments plots, particularly at the Golden Downs site, but this was allowed for by adjusting the length of each stake left above the ground, keeping the tops of the stakes on a horizontal plane.

5.2.2: Litter Collection and Analysis

The litter in the traps was collected every six months after installation, and this continued until at least two consecutive litter collections had occurred at every LTSP site. The first round of litter collections from the traps at the sites occurred in summer 2003, the second in winter 2003 and the last collection round was in summer 2004. The litter was removed from the traps by hand, taking care to avoid including any grasses or other plant material that had grown up through the bottom of the trap. Any large pieces of woody debris in the traps were broken up into smaller pieces, and the collected material was placed in a paper bag. This material was then taken back to the laboratory for analysis. A small number of traps were damaged in some way between litter collections, and when found these traps were repaired in the field. If the damage to a given trap could have influenced the effectiveness of litter collection, the data produced from the damaged trap was not included in the later analyses, as the data may have been unrepresentative.

The oven dry, ash free masses of the plant litter collected in the litter traps were determined as described in Section 2.2.3. It was decided to remove all large pieces of woody debris from the litter samples prior to weighing, as woody debris was found very rarely in the litter traps, but when present tended to triple or quadruple the mass of the litter collected, potentially skewing the results and preventing the detection of treatment effects. The carbon and nitrogen content of the litter was also determined as described in Section 2.2.3.

5.2.3: Forest Productivity Data

The forest productivity data was supplied by Mark Kimberley (2006), and was generated using an algorithm called the 300 Index. Using the values for tree volume, height, stand age and other factors describing the initial nutritional characteristics of the site, the 300 Index can be used to calculate the projected mean annual incremental increase in the stem volume of the trees in a stand at age 30, assuming a stand density of 300 stems per hectare by age 30. This data can then be used to infer the relative rates of growth of the trees, and the time it will take for the trees to reach certain volumes. A full description and discussion of the 300 Index growth model was presented by Kimberley *et al*. (2005), and as the model has been found to perform well in a range of *P. radiata* plantations around New Zealand, it was concluded that the 300 Index data could be used in this study with confidence.

Although other more direct measurements of stand productivity were available, such as the annual increments in tree height and stand volume, these could not be used to determine the relative effects of the treatments on tree growth at the between the sites, due to the substantial differences in stand age. The 300 Index is able to account for this age-based variation, and can therefore be used to accurately compare the effects of the treatments at the different sites.

5.2.4: Statistical Analysis

The effects of the treatments on the mass and characteristics of the litter was determined using ANOVA and Tukey’s multiple comparison analysis test, as described in Section 2.2.5, and multiple stepwise regression was used to identify any statistical relationships between the parameters measured in the previous chapters and the production and characteristics of the litter. The same procedures were followed with the 300 Index data to determine the effects of the treatments, and the relationships between the 300 Index data and the environmental conditions.

5.3: RESULTS

The effects of fertilisation and organic matter removal on litterfall production and litterfall nutrient characteristics at the individual LTSP sites are presented in Tables 5.1 – 5.6. The mean oven dry, ash free mass of litter collected from the treatment plots is given, as well as the carbon content, nitrogen content and the carbon: nitrogen ratio of the litter. The effects of the treatments on the 300 Index figures is presented in Table 5.7

The standard error of the mean (SEM) of the litterfall and 300 Index values are given presented in parentheses under the relevant value, and any statistical differences in the mean values between the levels of treatments are indicated by a letter or letters. If no letter is present, the values are indistinct at $\alpha = 0.05$ and there was no statistical difference between the treatment levels. Full summaries of the ANOVA calculations are presented in Statistical Appendices Five and Six (S. App. 5 and S. App. 6 respectively).

The results of the regression analysis between the physical, chemical and microbiological parameters and the 300 Index values at the sites in each sampling round are presented in Table 5.4 and 5.5. As only one set of 300 Index values were available for each treatment plot, the parameters varied with sampling round, but the 300 Index values were the same. The statistical significance and degree of variation (r^2) explained by each model is reported, as are the parameters, coefficients and intercepts used to generate the models. The terms used to describe the physical and chemical parameters in the tables are the same as described previously in Section 2.3, and the terms used to describe the microbiological parameters are the same as in Section 4.3. In cases where multiple parameters were calculated to be significant predictors of the 300 Index values, they are listed in order of importance to the model, and the relative importance of each parameter is also reported.

5.3.1: Effects of Fertilisation and Organic Matter Removal on Litterfall

Table 5.1: Litterfall Mass and Nutritional Characteristics at Woodhill

COLLECTION PERIOD	Production (g / day)	% Carbon (g / 100g)	% Nitrogen (g / 100g)	Carbon: Nitrogen ratio
ONE				
FERT	0.45	53.47	0.81 **a**	67.46 **a**
	(0.03)	(0.26)	(0.04)	(3.33)
NO FERT	0.39	53.36	0.94 **b**	57.36 **b**
	(0.04)	(0.17)	(0.03)	(1.50)
FF	0.39	53.39	0.82	65.48
	(0.04)	(0.15)	(0.03)	(2.84)
WT	0.45	53.56	0.95	57.22
	(0.03)	(0.23)	(0.04)	(2.33)
SO	0.42	53.29	0.85	64.54
	(0.06)	(0.37)	(0.06)	(4.73)
TWO				
FERT	0.98	53.87	0.92 **a**	58.50 **a**
	(0.04)	(0.12)	(0.02)	(1.21)
NO FERT	0.79	54.11	0.81 **b**	67.18 **b**
	(0.07)	(0.09)	(0.02)	(1.87)
FF	0.86	53.90	0.88	62.23
	(0.05)	(0.12)	(0.04)	(2.92)
WT	0.91	54.09	0.86	63.20
	(0.06)	(0.04)	(0.03)	(2.31)
SO	0.88	53.98	0.86	63.10
	(0.12)	(0.20)	(0.03)	(2.58)
THREE				
FERT	0.72	53.80	0.89	61.10
	(0.07)	(0.11)	(0.03)	(2.32)
NO FERT	0.50	53.86	0.80	68.72
	(0.06)	(0.12)	(0.04)	(3.50)
FF	0.65	53.76 **a b**	0.88	62.44
	(0.04)	(0.12)	(0.05)	(4.04)
WT	0.57	54.14 **a**	0.85	63.88
	(0.08)	(0.07)	(0.03)	(1.82)
SO	0.59	53.58 **b**	0.81	68.41
	(0.13)	(0.11)	(0.05)	(4.90)
ALL				
FERT	0.71 **a**	53.71	0.88	62.36
	(0.05)	(0.11)	(0.02)	(1.59)
NO FERT	0.56 **b**	53.78	0.85	64.42
	(0.05)	(0.10)	(0.02)	(1.71)
FF	0.63	53.68	0.86	63.39
	(0.05)	(0.09)	(0.02)	(1.94)
WT	0.65	53.93	0.89	61.43
	(0.06)	(0.10	(0.02)	(1.44)
SO	0.63	53.62	0.84	65.35
	(0.08)	(0.16)	(0.03)	(2.49)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

The fertilisation and organic matter removal treatments had few consistent significant effects on litter production and nutrient content at Woodhill in any of the three collection periods (Table 5.1). The significant effect of fertilisation on the nitrogen content of the litter was inconsistent across the first two collections, and this was also observed in the effects of fertilisation on the carbon: nitrogen ratio of the litter. Fertilisation did tend to increase the total mass of litterfall production, and the magnitude of this increase was significant when the data from all collections was analysed. The differences in litter production were also close to statistical significance in the individual sampling rounds (Pr (F) = 0.33, 0.09 and 0.06 for collections 1, 2 and 3 respectively). The organic matter removal treatment produced one significant effect on the carbon content of the litter, as the carbon content of the litter produced in the WT treatment plots was greater than that in the SO treatment plots in the third collection period (Pr (F) = 0.015), but in general organic matter removal did not strongly influence litterfall production or nutrient content at Woodhill.

Table 5.2 Litterfall Mass and Nutritional Characteristics at Tarawera

COLLECTION PERIOD	Production (g / day)	% Carbon (g / 100g)		% Nitrogen (g / 100g)	Carbon: Nitrogen ratio	
TWO						
FERT	0.71	55.88	**a**	0.68	82.23	
	(0.07)	(0.10)		(0.02)	(1.76)	
NO FERT	0.62	55.42	**b**	0.64	88.67	
	(0.05)	(0.08)		(0.03)	(4.29)	
FF	0.62	55.65		0.67	83.21	
	(0.04)	(0.11)		(0.02)	(2.73)	
WT	0.78	55.51		0.65	86.29	
	(0.1)	(0.15)		(0.02)	(2.77)	
SO	0.61	55.78		0.67	86.86	
	(0.05)	(0.13)		(0.05)	(6.01)	
THREE						
FERT	0.97	54.00		0.66	83.02	**a**
	(0.06)	(0.11)		(0.02)	(2.42)	
NO FERT	0.84	54.10		0.60	91.77	**b**
	(0.04)	(0.10)		(0.02)	(2.56)	
FF	0.87	53.94		0.61	88.86	
	(0.09)	(0.15)		(0.02)	(3.33)	
WT	0.95	54.13		0.61	88.53	
	(0.06)	(0.13)		(0.01)	(2.02)	
SO	0.89	54.07		0.65	84.79	
	(0.06)	(0.09)		(0.03)	(4.32)	
ALL						
FERT	0.84	54.94		0.67	82.62	**a**
	(0.05)	(0.21)		(0.01)	(1.50	
NO FERT	0.73	54.76		0.62	90.22	**b**
	(0.04)	(0.15)		(0.02)	(2.52)	
FF	0.74	54.79		0.64	86.03	
	(0.06)	(0.23)		(0.02)	(2.27)	
WT	0.86	54.82		0.63	87.41	
	(0.06)	(0.20		(0.01)	(1.74)	
SO	0.75	54.93		0.66	85.82	
	(0.05)	(0.23)		(0.03)	(3.71)	

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

The fertilisation treatment decreased the carbon: nitrogen ratio of the litter, and the decrease was significant in the second collection, and across all collection combined, as shown in Table5.2. The carbon content of the litter was increased by fertilisation in the first collection, but this was not consistently observed. Litter production tended to be greater in the fertilised treatment plots, but the differences were not statistically significant (S. App. 5.2). The organic matter removal treatments did not consistently influence the production or nutrient contents of the litter collected in the traps.

Table 5.3 Litterfall Mass and Nutritional Characteristics at Berwick

COLLECTION PERIOD	Production (g / day)	% Carbon (g / 100g)		% Nitrogen (g / 100g)		Carbon: Nitrogen ratio	
ONE							
FERT	0.74	53.62	**a**	0.90	**a**	60.07	
	(0.14)	(0.10)		(0.03)		(1.91)	
NO FERT	1.00	53.16	**b**	0.79	**b**	68.17	
	(0.21)	(0.08)		(0.03)		(2.30)	
WT	0.80	53.41		0.81		66.97	
	(0.16)	(0.14)		(0.03)		(2.49)	
SO	0.95	53.36		0.88		61.28	
	(0.20)	(0.09)		(0.03)		(2.20)	
TWO							
FERT	1.22	53.31		0.75		72.69	
	(0.19)	(0.17)		(0.04)		(3.47)	
NO FERT	1.56	53.01		0.76		70.97	
	(0.15)	(0.2)		(0.03)		(3.22)	
WT	1.19	53.19		0.73		73.88	
	(0.14)	(0.21)		(0.03)		(3.32)	
SO	1.59	53.14		0.77		69.78	
	(0.19)	(0.17)		(0.04)		(3.23)	
THREE							
FERT	0.83	53.72	**a**	0.94	**a**	58.35	**a**
	(0.14)	(0.11)		(0.04)		(2.62)	
NO FERT	0.97	53.37	**b**	0.81	**b**	66.88	**b**
	(0.09)	(0.08)		(0.03)		(2.17)	
WT	0.79	53.58		0.83		65.67	
	(0.12)	(0.14)		(0.04)		(2.58)	
SO	1.01	53.51		0.91		59.56	
	(0.11)	(0.08)		(0.04)		(2.67)	
ALL							
FERT	0.93	53.55	**a**	0.86	**a**	63.70	**a**
	(0.10)	(0.08)		(0.03)		(2.05)	
NO FERT	1.18	53.18	**b**	0.78	**b**	68.67	**b**
	(0.11)	(0.08)		(0.02)		(1.54)	
WT	0.92	53.39		0.79	**a**	68.84	**a**
	(0.09)	(0.1)		(0.02)		(1.79)	
SO	1.18	53.34		0.86	**b**	63.54	**b**
	(0.12)	(0.08)		(0.02)		(1.82)	

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

The carbon and nitrogen content of the litterfall at Berwick tended to be increased by fertilisation, although the relative effect on nitrogen content was greater, as was evident in the statistical decreases in the carbon: nitrogen ratio of the litter (Table 5.3). Increased organic matter removal statistically decreased the nitrogen content and increased the carbon: nitrogen ratio of the litterfall across all collection periods. The rate of litterfall production was influenced consistently by both fertilisation and organic matter removal, but the differences were not statistically significant (S. App. 5.3).

Table 5.4 Litterfall Mass and Nutritional Characteristics at Burnham

COLLECTION PERIOD	Production (g / day)		% Carbon (g / 100g)	% Nitrogen (g / 100g)		Carbon: Nitrogen ratio	
ONE							
FERT	1.03	**a**	53.77	1.00	**a**	54.66	**a**
	(0.14)		(0.11)	(0.05)		(2.24)	
NO FERT	0.65	**b**	53.62	0.70	**b**	78.44	**b**
	(0.06)		(0.04)	(0.04)		(4.36)	
WT	0.81		53.76	0.83		66.61	
	(0.12)		(0.08)	(0.05)		(4.36)	
SO	0.88		53.63	0.87		66.49	
	(0.13)		(0.08)	(0.08)		(6.35)	
TWO							
FERT	1.12		53.38	0.82		66.10	
	(0.12)		(0.13)	(0.03)		(2.18)	
NO FERT	0.98		53.34	0.74		72.99	
	(0.06)		(0.05)	(0.02)		(2.57)	
WT	1.05		53.31	0.78		69.50	
	(0.12)		(0.08)	(0.04)		(3.40)	
SO	1.05		53.41	0.77		69.58	
	(0.08)		(0.11)	(0.02)		(1.65)	
THREE							
FERT	1.24		53.76	1.03	**a**	53.25	**a**
	(0.23)		(0.12)	(0.05)		(2.39)	
NO FERT	1.09		53.51	0.83	**b**	64.81	**b**
	(0.1)		(0.15)	(0.02)		(1.31)	
WT	1.00		53.65	0.88	**a**	61.36	
	(0.19)		(0.17)	(0.02)		(1.42)	
SO	1.33		53.62	0.98	**b**	56.70	
	(0.14)		(0.10)	(0.06)		(3.52)	
ALL							
FERT	1.13		53.64	0.95	**a**	58.00	**a**
	(0.10)		(0.08)	(0.03)		(1.76)	
NO FERT	0.91		53.49	0.76	**b**	72.08	**b**
	(0.06)		(0.06)	(0.02)		(2.08)	
WT	0.95		53.58	0.83		65.83	
	(0.09)		(0.08)	(0.02)		(2.02)	
SO	1.08		53.55	0.87		64.26	
	(0.08)		(0.06)	(0.04)		(2.72)	

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Fertilisation tended to increase litter production, carbon content and nitrogen content at Burnham, and decrease the carbon: nitrogen ratio of the litter (Table 5.4), although the differences were generally not statistically significant (S. App. 5.4). There was one significant difference between the levels of the organic matter removal treatment in the nitrogen content of the litter, but this was observed only once.

Four significant treatment interactions terms were calculated in the Burnham litterfall data (S. App. 5.4). The carbon content of the litter collected between summer 2003 and winter 2003 (Collection Two) at Burnham was greater in the fertilised WT treatment plots than in the fertilised SO treatment plots, but in the unfertilised plots the carbon content of the litterfall was greater in the SO treatment plots. This result was reversed in the analysis of the carbon content of the litterfall between winter 2003 and summer 2004 (Collection Three), as the carbon content of the litterfall was greater in the fertilised SO treatment plots than in the fertilised WT plots, and greater in the unfertilised WT treatment plots than in the unfertilised SO treatment plots. The effect of organic matter removal on the nitrogen content of the litterfall at Burnham during the third collection period was also influenced by fertilisation, as there was no difference between the unfertilised WT and SO treatment plots, but the nitrogen content of the litterfall in the fertilised SO treatment plots was greater than that in the fertilised WT treatment plots, and the carbon: nitrogen ratio of the litter was also lower.

Table 5.5 Litterfall Mass and Nutritional Characteristics at Kinleith

COLLECTION PERIOD	Production (g / day)	% Carbon (g / 100g)	% Nitrogen (g / 100g)	Carbon: Nitrogen ratio
TWO				
FERT	0.38	54.46	1.00	55.60
	(0.05)	(0.23)	(0.05)	(2.45)
NO FERT	0.32	54.09	0.97	57.78
	(0.05)	(0.3)	(0.05)	(3.17)
FF	0.34	54.47	0.97	57.27
	(0.05)	(0.31)	(0.05)	(3.07)
WT	0.34	54.27	0.93	60.66
	(0.06)	(0.34)	(0.06)	(4.30)
SO	0.38	54.09	1.05	52.14
	(0.07)	(0.34)	(0.04)	(2.03)
THREE				
FERT	0.59	54.50	1.05	52.78
	(0.05)	(0.11)	(0.05)	(2.06)
NO FERT	0.46	54.46	0.96	58.83
	(0.05)	(0.12)	(0.05)	(3.09)
FF	0.55	54.48	0.98	57.08
	(0.05)	(0.1)	(0.06)	(3.61)
WT	0.45	54.42	0.95	58.34
	(0.07)	(0.09)	(0.04)	(3.29)
SO	0.58	54.52	1.08	52.01
	(0.06)	(0.2)	(0.07)	(2.79)
ALL				
FERT	0.49	54.48	1.03	54.19
	(0.04)	(0.13)	(0.03)	(1.63)
NO FERT	0.39	54.27	0.96	58.31
	(0.04)	(0.17)	(0.03)	(2.22)
FF	0.44	54.48	0.98	57.17
	(0.04)	(0.16)	(0.04)	(2.37)
WT	0.40	54.35	0.94	59.5
	(0.05)	(0.18)	(0.04)	(2.72)
SO	0.48	54.31	1.06	52.07
	(0.05)	(0.2)	(0.04)	(1.72)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Neither the fertilisation nor organic matter removal treatments were found to statistically influence the characteristics of litterfall at Kinleith (Table 5.5). Litter production tended to be greater in fertilised plots, and was close to statistical significance when the data from both collections was combined (Pr (F) = 0.072), but no other strong trends were evident.

Table 5.6 Litterfall Mass and Nutritional Characteristics at Golden Downs

COLLECTION PERIOD	Production (g / day)	% Carbon (g / 100g)		% Nitrogen (g / 100g)	Carbon: Nitrogen ratio
ONE					
FERT	0.68	52.40		0.71	76.74
	(0.09)	(0.17)		(0.04)	(4.40)
NO FERT	0.55	52.23		0.75	70.74
	(0.05)	(0.18)		(0.03)	(2.26)
FF	0.55	52.50		0.76	71.17
	(0.08)	(0.26)		(0.04)	(4.62)
WT	0.56	52.08		0.73	73.28
	(0.11)	(0.23)		(0.04)	(3.87)
SO	0.72	52.37		0.70	76.77
	(0.06)	(0.09)		(0.04)	(4.50)
TWO					
FERT	0.72	53.34		0.79	68.28
	(0.04)	(0.26)		(0.02)	(2.07)
NO FERT	0.80	53.64		0.76	71.69
	(0.09)	(0.16)		(0.03)	(2.80)
FF	0.82	53.65	**a b**	0.79	69.04
	(0.11)	(0.08)		(0.04)	(3.42)
WT	0.72	52.91	**a**	0.75	71.40
	(0.05)	(0.27)		(0.03)	(3.16)
SO	0.73	53.91	**b**	0.78	69.52
	(0.10)	(0.26)		(0.03)	(2.51)
ALL					
FERT	0.70	52.87		0.75	72.51
	(0.05)	(0.18)		(0.03)	(2.58)
NO FERT	0.67	52.94		0.76	71.22
	(0.06)	(0.19)		(0.02)	(1.80)
FF	0.68	53.08	**b**	0.78	70.11
	(0.07)	(0.20)		(0.03)	(2.89)
WT	0.64	52.50	**a**	0.74	72.34
	(0.06)	(0.20)		(0.03)	(2.51)
SO	0.73	53.14	**b**	0.74	73.15
	(0.06)	(0.24)		(0.03)	(2.73)

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

Fertilisation did not significantly influence the production or nutrient content of the litterfall at Golden Downs (Table 5.6). Organic matter removal was found to significantly influence only one parameter of the litterfall. The carbon content of the litter was found to be lower in the WT treatment plots than in the FF or SO treatment plots, and the difference in carbon content was statistical over the second collection period and also when the data from both collections was combined. The effects of organic matter removal on the other litterfall characteristics were idiosyncratic, and no trends were consistently observed.

5.3.2: Effects of Fertilisation and Organic Matter Removal on Productivity

Table 5.7: Mean 300 Index Values at the LTSP Sites

SITE	300 Index					
WOODHILL	F	23.4 (0.49)	**a**	FF	20.3 (1.10)	
	NF	18.9 (0.45)	**b**	WT	21.4 (1.11)	
				SO	21.7 (0.96)	
TARAWERA	F	27.6 (0.38)		FF	26.8 (0.33)	
	NF	26.8 (0.33)		WT	27.3 (0.62)	
				SO	27.6 (0.34)	
BERWICK	F	26.1 (0.88)		WT	26.7 (0.31)	
	NF	26.6 (0.48)		SO	26.0 (0.94)	
BURNHAM	F	25.9 (0.20)		WT	25.8 (0.22)	
	NF	25.7 (0.18)		SO	25.8 (0.17)	
KINLEITH	F	24.5 (0.53)		FF	23.2 (0.27)	**a**
	NF	23.6 (0.35)		WT	23.8 (0.45)	**a b**
				SO	25.1 (0.68)	**b**
GOLDEN DOWNS	F	25.4 (0.40)		FF	24.9 (0.59)	
	NF	24.6 (0.33)		WT	25.6 (0.45)	
				SO	24.6 (0.20)	
ALL SITES	F	25.5 (0.27)	**a**	WT	25.3 (0.35)	
	NF	24.4 (0.36)	**b**	SO	25.3 (0.35)	
WOODHILL / TARAWERA / KINLEITH / GOLDEN DOWNS				FF	24.0 (0.51)	**a**
				WT	24.7 (0.50)	**a b**
				SO	25.0 (0.46)	**b**

Letters in bold indicate statistical groupings based on Tukey's multi-comparison analysis test

At the individual LTSP sites, fertilisation was found to significantly increase the estimated growth rate of the trees at Woodhill (Table 5.7). The response of the estimated growth rates to fertilisation at the five other LTSP sites was not statistically significant (refer S. App. 6), although substantial increases were calculated for the Tarawera, Kinleith and Golden Downs sites. The 300 Index data from all sites was combined the estimated growth rate in the fertilised plots was still significantly greater (Pr (F) = 0.00).

There were no substantial differences in the 300 Index values calculated for the SO and WT treatment plots at the LTSP sites. However, at the four sites where all three organic matter removal treatments had been applied, the mean 300 Index values were consistently lowest in the FF treatment plots, and the decrease in the estimated growth rates in the FF treatment plots when compared to the SO plots were significant at Kinleith, and across all sites combined.

5.3.3: Statistical Relationships between Productivity and the Environmental and Microbiological Parameters

Table 5.8: Relationships between Parameters and 300 Index Values in Summer 2002

Site	R^2	p Value	300 Index Values Parameters	Individual r^2	Coefficients	Intercept
Woodhill	0.83	0.000	FH % N	0.83	6.41	15.20
Tarawera	0.56	0.000	S240 NP Soil Biomass	0.31 0.25	-2.81 0.28	30.14
Berwick	0.76	0.000	S120 AA FH % N	0.45 0.31	-7.52 -6.40	41.57
Burnham	0.59	0.003	FH Moisture F120 CHO	0.30 0.29	9.42 -0.85	22.56
Kinleith	0.30	0.022	FH Mass C S240 AA	0.22 0.08	2.64 -2.19	26.44
Golden Downs	0.45	0.002	F240 CHO Soil C:N	0.29 0.16	0.85 -0.19	26.46
All Sites	0.62	0.000	S240 NP FH Moisture FH Density Soil C:N S120 NP	0.22 0.14 0.13 0.07 0.06	-1.90 8.10 -0.02 -0.12 1.53	27.07

The regression models calculated from the summer 2002 parameters at the LTSP sites related reasonably well to the 300 Index values ($R^2 = 0.30$ – 0.83), and the degree of variation in the estimated growth rate explained by the regression models for all six sites combined was also substantial (0.62). The parameters that were related to the 300 Index in summer 2002 varied substantially with site. At Woodhill and Kinleith, parameters describing the nutrient status of the of the treatment plots were most related to the 300 Index values, while at Burnham the moisture content of the FH litter was most closely related to estimated growth rates, and these parameters were all positively related to the estimated growth rates. At Tarawera, Berwick, and Golden Downs, the total utilisation of various Biolog substrate groups by the microbial community were the most important components of the regression models, but the nature of the relationship between the 300 Index values and the substrate utilisation parameters varied across the sites.

Across all six sites, the parameter most related to the 300 Index values in the treatment plots was the utilisation of the nitrogen and phosphorous sources by the soil microbial community after 240 hours (S240 NP), and this parameter was also negatively correlated to the estimated growth rates. Several other parameters were also related to 300 Index, all were substantially less important to the accuracy of the model.

Table 5.9: Relationships between Parameters and 300 Index Values in Summer 2003

Site	300 Index Values					
	R^2	p Value	Parameters	Individual r^2	Coefficients	Intercept
Woodhill	0.78	0.000	FH Mass N	0.78	96.05	17.74
Tarawera	0.34	0.013	FH Mass N S240 CHO	0.20 0.14	45.53 1.26	24.75
Berwick	No Relationship					
Burnham	0.54	0.022	FH Moisture Soil Biomass FH Density	0.31 0.15 0.08	7.43 0.12 -0.01	24.06
Kinleith	0.40	0.005	F120 F240 CHO	0.35 0.05	0.89 -0.79	22.91
Golden Downs	0.42	0.011	S120 CARB S120 CHO S240 CARB	0.29 0.08 0.05	-8.63 4.11 -1.60	27.13
All Sites	0.65	0.000	FH Moisture FH Mass N Soil Biomass F120 AA FH Mass C FH Density S120 CHO FH Biomass	0.16 0.12 0.10 0.10 0.06 0.05 0.04 0.03	-9.59 126.98 0.05 1.95 -2.64 -0.01 0.89 -0.01	26.15

In general, the degree of variation in the 300 Index values explained by the summer 2003 regression models was greater than that in 2002, although a statistically significant model was not able to be calculated for the Berwick site in 2003 (Table 5.9). The parameters that were statistically the most important to the regression models for the individual sites also varied with year. At Woodhill and Tarawera, the mass of nitrogen in the FH litter were the most important components of the regression models, and were positively related to the estimated growth rates. The moisture content of the FH litter was the parameter most closely related to the 300 Index values at Burnham in 2003, and was positively correlated to estimated growth rates. Parameters describing the microbiological community were most related to the 300 Index at Kinleith and Golden Downs, as the most important components of the models at the sites were the utilisation of all substrate by the FH litter microbial community (F120) and the utilisation of carboxylic acids by the soil microbial community (S120 CARB) respectively.

The regression model for all sites in 2003 accounted for approximately the same degree of variation in the 300 Index values as the 2002 regression model (Tables 5.8 and 5.9). The moisture content of the FH litter was the most important parameter in the 2003 model, but the degree of variation accounted for by this parameter was not great ($r^2 = 0.16$). FH litter moisture was negatively related to estimated growth, indicating that more growth was anticipated in treatment plots with less moisture in the FH litter. Various other parameters were also statistically related to the estimated growth rates in all of the treatment plots, and these accounted for more variation than FH litter moisture when combined.

The regression models for all sites combined in 2002 and 2003 were also applied to the data for the individual sites in 2002 and 2003 to determine if the overall models accurately predicted the 300 Index values at the individual sites. The plots of the actual and predicted 300 Index values are shown below in Figures 5.1 and 5.2, and the R^2 values for each site are given in Table 5.10.

Figure 5.1: Relationship between Actual 300 Index Values and Predicted 300 Index Values at the LTSP sites in 2002

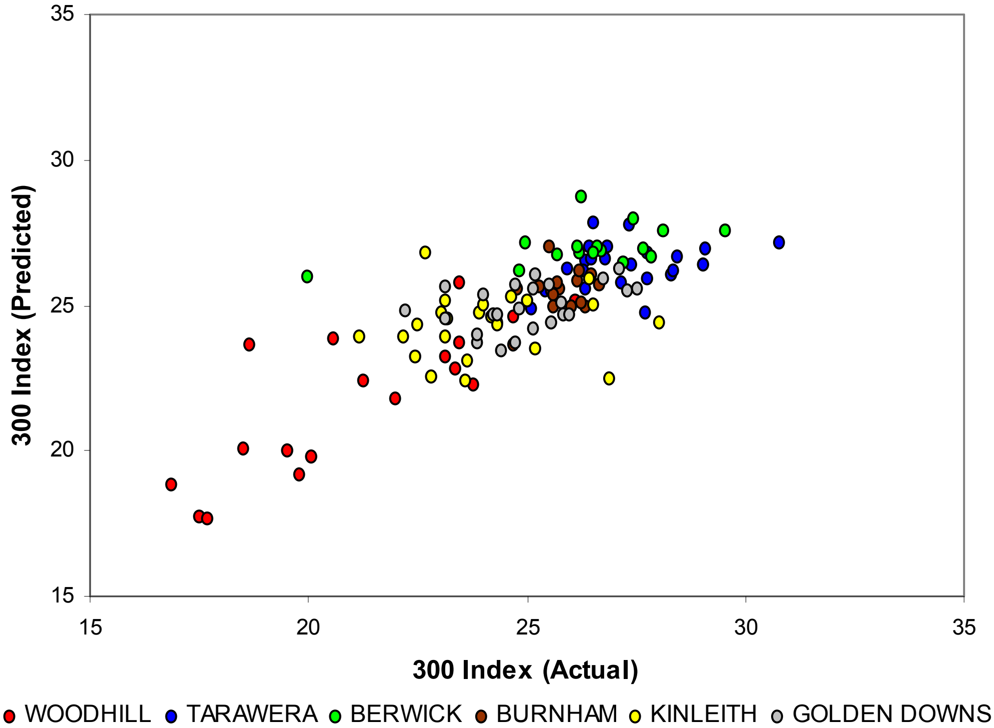


Figure 5.2: Relationship between Actual 300 Index Values and Predicted 300 Index Values at the LTSP sites in 2003

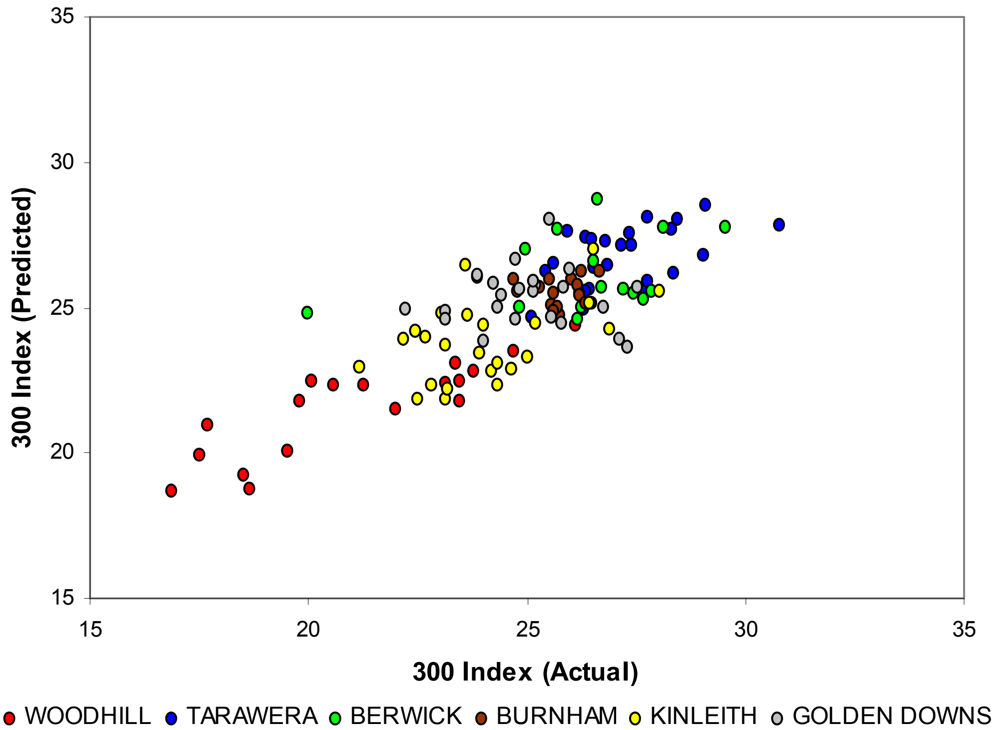


Table 5.10: Correlation between actual 300 Index Values and 300 Index Values calculated with the All Sites models

Site	R^2 in 2002	R^2 in 2003
Woodhill	0.66	0.75
Tarawera	0.11	0.27
Berwick	0.23	0.13
Burnham	0.09	0.00
Kinleith	0.01	0.24
Golden Downs	0.19	0.01
All Sites	0.62	0.65

The regression models for all sites combined accurately predicted the 300 Index values at Woodhill in 2002 and 2003, as evidenced by the relatively linear distribution of points representing Woodhill in Figures 5.1 and 5.2, and the high R^2 values in Table 5.10. This relationship was not observed consistently at any other site, however, as the data points representing the five other LTSP sites tended to cluster, and the R^2 values were substantially lower and not consistent from 2002 to 2003.

5.4: DISCUSSION

5.4.1: Litterfall Production

Temporal Variations

The rate of litter production at the LTSP sites tended to vary with the time of collection, as did the carbon content, nitrogen content and carbon: nitrogen ratio of the litter. Seasonal variations in litterfall characteristics have been reported in numerous forest ecosystems (Bray and Gorham, 1964; Gosz *et al*., 1972; Pregitzer and Burton, 1991), and such variations were found at the LTSP sites. However, there were substantial variations in the temporal patterns at the different sites, as the greatest rate of litter fall at Woodhill and Berwick was from summer 2003 to winter 2003 (Collection Two), while at Tarawera and Kinleith significantly more litterfall occurred from winter 2003 to summer 2004 (Collection Three). Variations were found in the carbon content of the litterfall, which was greatest from summer 2003 to winter 2003 at Woodhill, Tarawera, Berwick, but not at Burnham and Golden Downs. The nitrogen content and carbon: nitrogen ratio of the litter varied between collection rounds at the sites in this way also.

It may be that the differences in the climatic conditions at the sites may have influenced the seasonal trends of litter production and nutrient content, and particular events such as storms may have inflated litterfall in some instances, but this cannot be proven at this time.

Effects of Fertilisation

Fertilisation tended to increase litter production at the LTSP sites, and also tended to increase the carbon and nitrogen content of the litter, although the increase in the nitrogen content was proportionally greater. The carbon: nitrogen ratio of the litter was the most affected characteristic of the litter, and was significantly lower in the fertilised plots. The nitrogen concentration of foliar litter has been reported to increase in response the application of nitrogenous fertilisers (Smith *et al*., 2000; Lopez-Zamora *et al*., 2001, Nohrstedt, 2001), agreeing with the results reported in this study. The effects were also consistent with the effects of fertilisation on the FH litter reported in Chapter Two, as FH litter mass, carbon content and nitrogen content were all increased by fertilisation and the FH litter carbon: nitrogen ratio was decreased. Consequently, it was concluded that the effects of fertilisation on litterfall were the driving factors behind the influence of the fertiliser application on the FH litter characteristics, or at the very least were reinforcing those effects.

Effects of Organic Matter Removal

The organic matter removal treatments did not significantly influence either the rate or characteristics of litterfall at the majority of the LTSP sites, but some effects were found at the Berwick and Golden Downs sites. At Berwick (refer Table 5.3), the nitrogen content of the litterfall collected in the SO treatment plots tended to be greater than that in the WT treatment plots, and this was statistically observed when the data from all three litter collections at Berwick was combined. This difference was also reflected in the carbon: nitrogen ration of the litterfall at Berwick, as this was lower in the SO treatment plots. At Golden Downs, the carbon content of litterfall collected in the WT treatment plots was lower than that collected in the FF and SO treatment plots, and these differences were significant in two cases (Table 5.6). Little comparative data regarding the effects of organic matter removal programs on litterfall in plantation forests is available. In the study carried out by Smith *et al*. (2000) at the Woodhill, Tarawera and Kinleith sites, it was found that organic matter removal did not consistently influence the nutrient status of needles on the trees, and the results of this study suggests that this trend continues until the needles fall as litter, although additional work would be required to confirm this.

Although there were a few significant effects of organic matter removal on litterfall characteristics, it was concluded that litterfall in the *P. radiata* stands was not substantially influenced by the organic matter removal treatments. Consequently, it was also determined that the significant differences in the FH litter characteristics identified in Chapter Two were still predominantly driven by the organic matter removals that occurred at site establishment, rather than the ongoing influence of litterfall since the stands were planted.

Significant Treatment Interactions

The only site for which significant interactions terms between the effects of fertilisation and organic matter removal on litter production characteristics were calculated was Burnham (S. App. 5.4), and the interactions that were found at this site were not consistently observed across the different collection periods. Accordingly, it was concluded that the effects of fertiliser application did not significantly influence the effects of the organic matter removal treatments on litterfall production and characteristics at the LTSP sites.

5.4.2: 300 Index Growth Rate Estimates

Spatial Variations

The predicted growth rates of the *P. radiata* stands were found to vary considerably with site (S. App. 6), with the greatest mean growth rate estimates at Tarawera, and the lowest at Woodhill. These differences were expected, as the characteristics of the sites varied considerably (Tables 1.1 and 1.2). Similar variations have been reported previously in the literature, and have also been incorporated into models used to predict the growth rates of *P. radiata* in the Canterbury and Southland regions of New Zealand (Smith *et al*., 2000).

Effects of Fertilisation

Fertilisation did not uniformly increase the predicted growth rates at the individual LTSP sites. A significant increase in response to fertilisation was found at Woodhill, and at Tarawera, Kinleith and Golden Downs increases that were approaching statistical significance were also calculated (Pr (F) = 0.158, 0.172 and 0.160 respectively). Across all sites combined, fertilisation statistically increased the 300 Index growth rate estimates (Pr (F) = 0.00). This trend agrees with those reported previously regarding the influence of fertilisation on growth rates (Kenney, 1980; Smith *et al*., 2000; Nohrstedt *et al*., 2001). The site most influenced by fertilisation was Woodhill (Table 5.7), and as this site also contained the least nitrogen initially, it was speculated that this could be the cause of the relatively greater response to fertilisation, as has been reported previously (Keeney, 1980). However, it must be reiterated that Woodhill also received substantially more fertiliser than the other LTSP sites (Table 2.2), confounding attempts to compare the relative effects of fertilisation on growth rates at the different LTSP sites.

Effects of Organic Matter Removal

At the individual LTSP sites, the estimated growth rates of the *P. radiata* stands tended to be lower in the FF treatment plots than in the SO plots, but the differences were only statistically significant at Kinleith (Table 5.7). Across all sites with the FF treatment plots, the mean growth estimates were also significantly lower in the FF plots than in the SO plots. No statistical differences between the WT and SO plots were found at any site. These results agree well with those of other investigations into the effects of increasing levels of post-harvest organic matter removal upon the growth rates of various species of trees (Dyck *et al*., 1989; Skinner *et al*., 1989; Proe and Dutch, 1994; Stone and Elioff, 1998; Stone and Kabzems, 2002; Corbeels *et al*., 2005). The decreased growth rates in the plots with greater levels of organic matter removal may have been the consequence of the reduction in available nutrients, as reported in Chapter Two. This conclusion is supported by the literature, as it has been found that harvesting methods that remove more than just the tree stems from a given site can substantially increase the loss of nitrogen and other nutrients, such as potassium, calcium and magnesium, and these losses have been related to decreased site productivity in subsequent rotations (Ballard, 2000, Corbeels *et al*., 2005). The decreased productivity in the treatment plots with greater levels of organic matter removal may also be associated with decreased moisture content in the FH litter and soil, as the availability of water has also been indicated to be important for the maintenance of productive capacity (Schoenholtz *et al*., 2000).

Significant Treatment Interactions

No significant interactions between the fertilisation and organic matter removal treatments were found in the statistical analysis of the 300 Index data, suggesting that the statistical decreases in estimated growth rates associated with the FF organic matter removal treatment at the Kinleith site individually and across all sites with the FF treatment were not being remediated by the application of fertiliser. Consequently, it was concluded that although fertilisation did tend to increase productivity, it did not induce the growth rates in the FF treatment plots to increase proportionally more than those in the WT or SO treatment plots, and growth rates in plots with a greater level of organic matter removal were not "catching up" to those in plots where organic matter retention had occurred.

5.4.3: Statistical Relationships between 300 Index and Environmental and Microbiological Parameters

Although the regression models presented in Table 5.8 and 5.9 tended to explain a reasonable degree of variation in the estimated growth rates of the trees in most cases, these results must be approached with much circumspection. At Woodhill, parameters describing aspects of the nutritional status of the sites were most related to the predicted growth rates at the sites, and this was also the case at Kinleith in 2002 and Tarawera in 2003. This can be explained with some confidence, particularly with regard to the Woodhill results, as increased nutrient availability was positively related to increased growth, as has been found previously (Kenney, 1980; Smith *et al*., 2000; Nohrstedt *et al*., 2001).

The statistical relationships between the Biolog parameters and the growth rates must be considered differently, however. Based on the methods that were employed in this study, it was not possible to separate differences in parameters of the productivity of the trees related directly to the addition of fertiliser or the removal of organic matter from the potential indirect effects of these treatments via the alterations they have made to the microbial community. However, the relationship between the parameters of productivity and the microbial community can be considered at the very least as relative indicators of productivity. For example, the microbial communities sampled from plots with high productivity may possess a certain set of characteristics, which results in comparatively greater utilisation of carbohydrates when incubated in a Biolog plate, as was the case at Golden Downs in 2002 (refer Table 5.8).

Another issue that questioned the validity of the relationships between the environmental and microbial parameters and the 300 Index values reported in this study was the significant variation in the statistically important parameters from 2002 to 2003. As discussed previously, in 2003 the sites were was substantially drier, and this influenced most of the parameters measured in the preceding chapters, and potentially placed the microbial communities at the sites under increased stress. This may have accounted for some of the annual variations in the correlations between the 300 Index values and the microbiological parameters, but the processes responsible for the variations are unknown, and cannot be commented upon with any confidence. One parameter was found to behave in a totally counter-intuitive manner, as it was calculated that increased growth rate estimates were found in sites with decreased FH litter moisture contents in 2003 – effectively, more growth was expected in the plots with less available moisture in the FH litter when overall water availability was decreased (refer Table 5.9). This result cannot be accounted for at this time.

The results of the application of the 2002 and 2003 all sites 300 Index regression models at the individual sites confirmed the site dependent nature of the parameters that were most related to productivity. As discussed previously, the overall regression models explained a reasonable degree of variation in the 300 Index values across all sites combined, but performed poorly at the individual sites with the exception of Woodhill (refer Table 5.10).

5.4.4: Conclusions

Although fertilisation tended to increase litterfall mass and nitrogen content, the lack of consistent statistically significant increases means that the first hypothesis of this chapter was not completely confirmed by the data. However, it was determined that the alterations to the litterfall characteristics induced by the application of fertiliser were found to be approximately the same as those caused by fertilisation in the FH litter layer on the forest floor, and consequently it was concluded that the effects of fertilisation on the litterfall characteristics may be the mechanism for the differences in FH litter characteristics found in the fertilised and unfertilised treatment plots at the LTSP sites. The second hypothesis was not proven, as the organic matter removal treatments did not consistently influence litterfall characteristics at the LTSP sites.

Rates of tree growth, as measured by the 300 Index, were not uniformly influenced by either fertilisation or organic matter removal at the individual sites, but significant effects across all sites were found. Fertilisation significantly increased productivity, and tree growth rates were also influenced by organic matter removal, as productivity in the FF treatment plots was lower than that in the SO treatment plots (Table 5.7), confirming both the third and fourth hypotheses of this chapter.

Finally, it was also found that the productivity at the sites was significantly related to parameters of the FH litter and soil microbial communities, as well as the parameters describing the physical and chemical environment. In general, the parameters describing the abiotic environment tended to explain a greater degree of variation in productivity, but this was not always the case as, as characteristics of the microbial community were most closely related to productivity at Golden Downs in particular, and in summer 2002 across all sites, total substrate utilisation by the soil community was the parameter most closely related to productivity (Table 5.8). However, as discussed previously, these results cannot be considered as evidence that the structure and activities of the microbial community are directly responsible for the differences productivity in the treatment plots, but rather that measurements of these parameters of the microbial community can be useful as indicators of productivity. Mechanisms do exist by which microbial communities can affect plant productivity, such as nitrogen mineralisation and the synthesis of phytohormones (Riggs *et al*., 2001; Bai *et al*., 2003), but as these mechanisms were not investigated in detail in this study, further comments regarding the nature of the relationship between microbial communities and tree productivity at the LTSP sites cannot be made.

CHAPTER SIX: OVERALL CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT

In this final chapter, the results presented and discussed in Chapters 2 to 5 will be considered with regard to the three main hypotheses set out in the first chapter (Section 1.7.2). This will be followed by a discussion regarding the potential implications of the results of this thesis, and future avenues of research will also be suggested.

6.1: EXAMINATION OF MAIN HYPOTHESES

1. **The application of fertilisation and organic matter removal at a range of sites has significantly altered the physical and chemical environment in the litter layer and soil.**

The results presented in Chapter Two supported this hypothesis, as all of the measured parameters used to describe the physical and chemical environment of the forest floor in the Long Term Site Productivity (LTSP) sites were significantly altered by one or both of the treatments in at least one of the sampling rounds. The magnitude of the response of several of the parameters to the fertilisation and organic matter removal treatments were found to vary substantially with site, and the effects of the treatments were consequently not significant across all six sites, but a number of consistent trends were observed, such as the increase in FH litter mass in response to fertilisation, and the decrease in FH litter mass in response to increasing levels of organic matter removal. Similarly strong trends in the moisture content of the FH litter and soil were also observed across the six LTSP sites, and the nitrogen content of the FH litter and soil was also found to increase in response to fertilisation and decrease in response to organic matter removal (refer Tables 2.10 – 2.12).

There was a substantial degree of temporal variation in some of the parameters, most notably at Woodhill, as the FH litter mass decreased greatly between summer 2002 and winter 2002 (Tables 2.4a and 2.4b), and the moisture content of the FH litter and soil also decreased in 2003. The latter variation was attributed to the decreased amount of rainfall in 2003 across the LTSP sites (refer Appendix One), but the substantial decrease in the FH litter mass at Woodhill over a six month interval was not as easily explained. The bulk of FH litter that was collected from Woodhill in summer 2002 had undergone substantial decay, but still met the criteria for inclusion as FH litter. After a further six months this material had degraded sufficiently to no longer be recognisable, and was therefore not included in the FH litter samples. Additionally, the relative magnitude of variation in the mean FH litter mass values at Woodhill did not vary substantially (Tables 2.4a and 2.4b), suggesting that variations in sampling technique were not responsible for causing the differences in the FH litter mass values. It was not known why there was a particularly substantial layer of plant litter material of a uniform age on the forest floor at Woodhill, as the age of the material indicated it was not the result of thinning, and it was suggested that the layer might have been the results of a windstorm or similar event.

However, it was readily apparent that the fertilisation and organic matter removal treatments have substantially altered the physical and chemical environment in the FH litter and upper soil layer of the LTSP treatment plots. This has implications regarding the physical nature of the habitat within the FH litter and soil, and also in terms of the quality of the FH litter on the forest floor, as parameters such as nitrogen content and the carbon: nitrogen ratio of the litter, which are indicative of litter quality (Worrell and Hampson, 1997; Grigal, 2000), were significantly affected by fertilisation in particular. Furthermore, the effects of treatments on the parameters were found to be long-term in nature, particularly in the case of the organic matter removal treatments, which were still significantly influencing FH litter and soil characteristics up to 17 years after application.

As discussed in Section 2.4.2, the trends in the responses of the physical and chemical parameters of the LTSP sites to the fertilisation and organic matter removal treatments were generally similar to those reported previously. However, it was apparent that the sensitivity and magnitude of the responses to the treatments at the six LTSP sites tended to be greater than those described in the literature, although some of this variation may have been the result of differences in factors such as climate, dominant tree species and sampling regimes.

2. The application of fertilisation and organic matter removal has produced significant variations in the characteristics of the microbial community at the sites, and these variations can be related to the changes in the physical and chemical environment caused by fertilisation and organic matter removal.

The biomass and substrate utilisation patterns of the microbial communities in the FH litter and soil were significantly affected by both the fertilisation and organic matter removal treatments at the LTSP sites, confirming the first part of this hypothesis. As with the response of the physical and chemical environment, the sensitivity and nature of the response of the microbial communities to fertilisation and organic matter removal varied across the different LTSP sites. However, as the characteristics of the microbial communities were also found to vary with site, the variation in response to the treatments was not unexpected, as the initial characteristics of the microbial communities at the six sites were not the same.

The second part of the hypothesis was also substantiated by the results, as it was found that the moisture content of the FH litter layer and the soil were statistically related to the parameters of the microbial community. As the fertilisation and organic matter removal treatments influenced these characteristics, it was concluded that alterations to the moisture content of the FH litter and soil in the treatments plots was the mechanism most responsible for the response of the microbial community to the treatments. This relationship also explained some of the temporal variations in the response of the microbial communities to the treatments, as FH litter and soil microbial biomass values fluctuated significantly with year, tending to decrease in 2003 when rainfall levels were substantially decreased relative to 2002, and this also explained some of the temporal variation in the patterns of substrate utilisation in 2002 and 2003.

Similar relationships between moisture availability and microbial biomass have been reported previously in the relevant literature for FH litter

(Dilly *et al*., 2001; Salamanca *et al*., 2002) and soil (Bååth and Söderström, 1982; Bohlen *et al*., 2001). However, other factors that have also been reported to significantly influence microbial biomass, such as litter quality and soil nutrient availability (Blagodatskaya and Anderson, 1998; Peacock *et al*., 2001; Li *et al*., 2004), were not found to be consistently related to microbial biomass in this study. Moisture availability in the FH litter and soil was also found to be the factor most consistently related to the relative patterns of substrate utilisation by the microbial communities, but this relationship was not supported by the results of other studies, which suggested that soil pH was a more influential factor (White *et al*., 2005). With regard to the organic matter removal treatments, these results also suggested that the moisture holding capacity of organic matter was more influential to the microbial communities than the nutrients contained in the organic matter, as the parameters describing nutrient availability at the LTSP sites were statistically less important than those describing moisture availability.

As with the effects of the treatments on the physical and chemical environment, the influence of fertilisation and organic matter removal on the characteristics of the FH litter and soil microbial community were found to be persistent, as the differences between the treatment plots were still highly significant up to 17 years after site establishment in the case of Woodhill. However, this was a logical outcome, as the physical and chemical environment was still significantly altered by the treatments, maintaining the variations in the selection pressures on the microbial communities inhabiting the different treatment plots.

3. The application of fertilisation and organic matter removal has significantly altered the productivity of the sites, and the variations in productivity can be related to the effects of the management practices on physical, chemical and microbiological characteristics at the sites.

The production and characteristics of litterfall at the LTSP sites were influenced by fertilisation in several cases, but the organic matter removal treatments had no consistent effect. The mean annual increments in wood volume as determined by the 300 Index values for production at the end of the rotation were influenced by both fertilisation and organic matter removal across all sites, although at the sites individually the effects of each treatment were observed statistically at only one site (Table 5.7). Consequently, it was determined that the first part of this hypothesis was generally supported by the results of Chapter Five, but as the hypothesis did not hold true at every site individually, this hypothesis was only partially confirmed. Additional measurements over the life of the trials may produce more statistically significant results, and will be required to conclusively determine if site productivity is uniformly influenced by the fertilisation and organic matter removal treatments at all of the LTSP sites.

Regression analysis determined that the 300 Index values were statistically related to various physical, chemical and microbiological characteristics of the treatment plots in almost every case (Table 5.8 and 5.9), and at the individual sites where the fertilisation and organic matter removal treatments had significantly altered productivity (Woodhill and Kinleith) the effects of the treatments on the parameters that were most closely related to productivity could be used to help explain the mechanism for the alterations to productivity. For example, at Woodhill, the 300 Index values were significantly lower in the unfertilised treatment plots than in the fertilised treatment plots (refer Table 5.7). The regression models for productivity at Woodhill identified the nitrogen content of the FH litter and the total mass of nitrogen held in the FH litter as the parameters most closely related to productivity in 2002 and 2003 respectively (refer Tables 5.8 and 5.9), and as these parameters were both significantly increased by fertilisation, (refer Table 2.4), this relationship can be used to explain why productivity in the fertilised treatment plots is greater than that in the unfertilised treatment plots at Woodhill.

A similar relationship between productivity, treatment effects and the physical, chemical and microbiological parameters was also found in the analyses of the combined sites data. In the majority of cases, the influence of the fertilisation and organic matter removal treatments on the parameters that were important to the 2002 and 2003 productivity regression models (Tables

5.8 and 5.9) was in agreement with the statistical effects of fertilisation and organic matter removal on the 300 Index values (Table 5.7). To give one example, in 2003 the F120 AA parameter, describing the utilisation of amino acids by the microbial community present in the FH litter layer, was positively related to increased productivity across all sites (Table 5.9). In 2003, this parameter was statistically increased by fertilisation and decreased by the FF organic matter removal treatment (Tables 4.1 and 4.5). This relationship holds true for the majority of the parameters used in the 2002 and 2003 productivity regression models, and can be used to explain why estimated productivity in the fertilised and SO treatment plots was higher than in unfertilised plots and in plots with greater levels of organic matter removal.

As a result of these relationships, the second part of this hypothesis can be confirmed with some confidence, as the variations in productivity were able to be related to the effects of the management practices on the physical, chemical and microbiological characteristics of the six LTSP sites. However, as the 300 Index values, although based on physical measurements of the trees, were only estimates of final productivity, further work extending until the end of the current rotation is required to conclusively determine the effects of the fertilisation and organic matter removal treatments on final wood production, and the relationship between site productivity and the characteristics of the site.

6.2: IMPLICATIONS FOR FOREST MANAGEMENT STRATEGIES

Relevance of Fertilisation and Organic Matter Removal Regimes

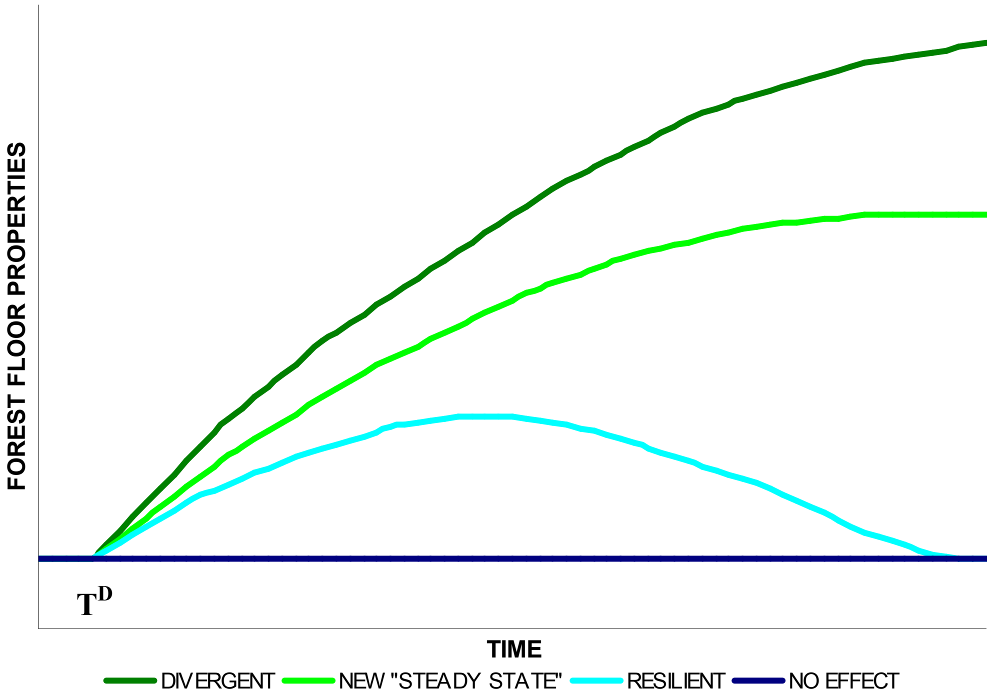
Prior to any discussion regarding the wider implications of the results presented in the previous chapters, the relevance of the fertilisation and organic matter removal treatments studied in this thesis must be assessed. The application of fertilisers to forest plantations in New Zealand is generally carried out with the intention of increasing growth rates, preventing the development of conditions caused by nutrient deficiencies and maintaining productivity over successive rotations (Mead, 2005). As fertilisers were applied to the LTSP sites with the intention of preventing any nutrient from becoming limiting to growth, the nutrient additions to the fertilised plots at the LTSP sites, particularly at Woodhill, were substantially greater than those currently suggested for exotic forest plantations in New Zealand (Mead, 2005). Consequently, the findings regarding fertilisation presented in this study have only limited relevance to conventional forestry management practices in New Zealand. However, the findings may have greater relevance to forestry in other parts of the world, as the indirect addition of significant masses of nitrogen to forest soils via atmospheric deposition in the Northern hemisphere has become a relatively common phenomenon, and over the life of a rotation has the potential to induce nitrogen additions equivalent to or exceeding those studied in this thesis at the LTSP sites (Markkola *et al*., 1995; Brandrud and Timmermann, 1998; Allen and Schlesinger, 2004; Sjöberg *et al*., 2004).

The different organic matter removal treatments examined in this thesis are representative of harvesting practices used in New Zealand, and around the world (Jorgensen *et al*., 1975; Bååth, 1980; Ohtonen *et al*., 1992; Bengtsson *et al*., 1998; Chow *et al*., 2002). Consequently, the findings reported in this thesis regarding the relative effects of the different types of organic matter removal associated with harvesting have relevance to the majority of conventional forestry management strategies.

Resilience of the Physical and Chemical Environment

The persistence of the differences in the physical and chemical characteristics of the various treatment plots has important implications regarding the resilience of the forest floor environment to disturbance. The resilience of an ecosystem refers to the capacity of the system, once disturbed, to return to the pre-disturbance state (Johnson, 1992; Sanchez *et al*., 2006). In the case of this study, the treatment plots that were considered to be disturbed were the fertilised and the WT and FF organic matter removal treatment plots, and were compared to the unfertilised and SO treatment plots respectively. Over the course of this study, significant differences were consistently found between the different levels of the fertilisation and organic matter removal treatments, and the differences will be discussed below using the terms introduced in Figure 6.1, which is a hypothetical model advanced in this thesis to describe resilience and other possible types of response to disturbance by a theoretical set of parameters used to described the forest floor environment.

Figure 6.1: Hypothetical Long-term Effects of Disturbance on Forest Floor Properties



The "No Effect" curve illustrates the case of a disturbance, occurring at time T^D, that does not significantly influence the parameters used to describe the forest floor properties, as the pre- and post-disturbance conditions are equivalent. The "Resilient" curve demonstrates a case where the disturbance has altered the forest floor properties, but the effects of the disturbance are only temporary, and the forest floor properties eventually return to the pre-disturbance state. The "New 'Steady State'" curve describes a permanent effect of the disturbance on the forest floor properties, and the relative differences in the forest floor properties between the post- and pre-disturbance (effectively the "No Effect curve") are persistent over time, although they do not diverge further. The "Divergent" curve represent the case wherein the disturbance has altered the forest floor conditions, and the difference in the properties relative to the initial conditions continues to diverge for the life of the rotation.

There was not enough data for the various physical and chemical parameters measured at the six LTSP sites to generate meaningful response curves similar to those described in Figure 6.1, as only some parameters were measured at site establishment and no regular measurements were taken prior to this study. However, as data regarding the initial relative differences in the mass of forest floor organic matter and total mass of nitrogen in the forest floor between the SO and the WT and FF treatment plots was collected at site establishment, and no further reinforcement of the organic matter removal treatments took place at the LTSP sites, some comparisons and deductions can be made regarding the potential longer term effects of the different levels of organic matter removal at the individual sites. The effects of the WT and FF organic matter removal treatments relative to the SO treatment are presented in Figures 6.2 – 6.7. As only mean values for the initial differences between the organic matter removal treatment plots were available at the Woodhill site, it was not possible to calculate the standard error of the mean (SEM), so error bars are not given for the initial differences in Figures 6.2a and 6.2b.

Figure 6.2a: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Woodhill

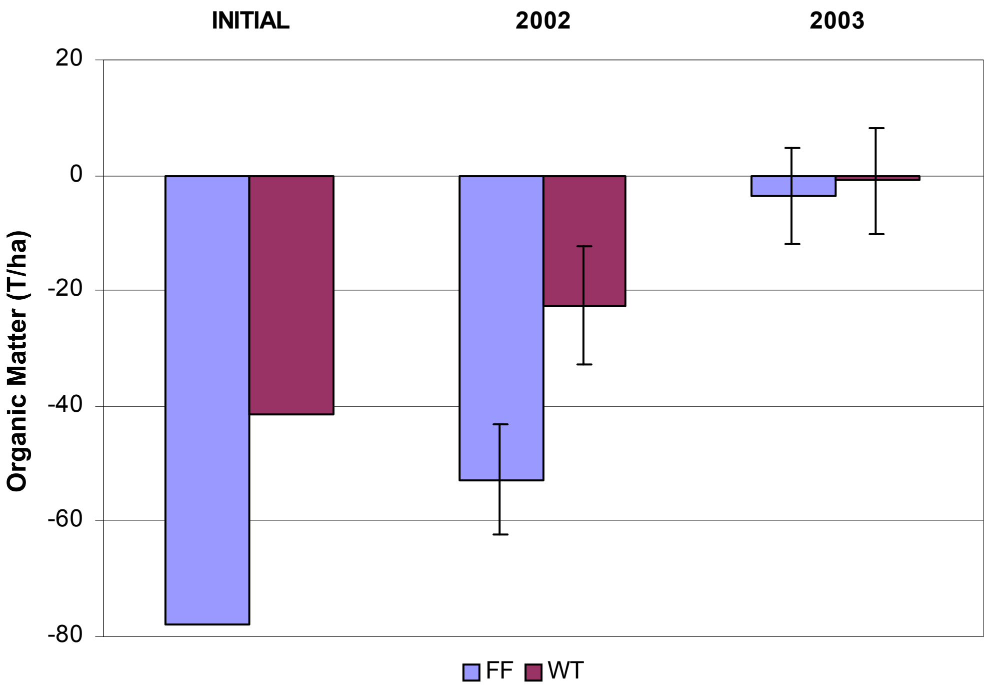


Figure 6.2b: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Woodhill

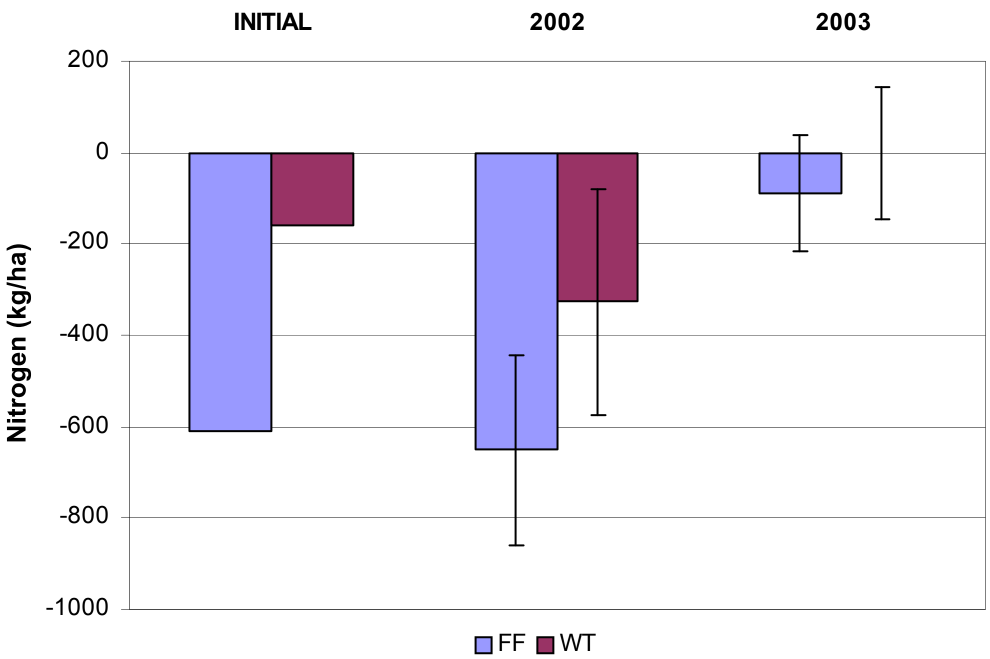


Figure 6.3a: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Tarawera

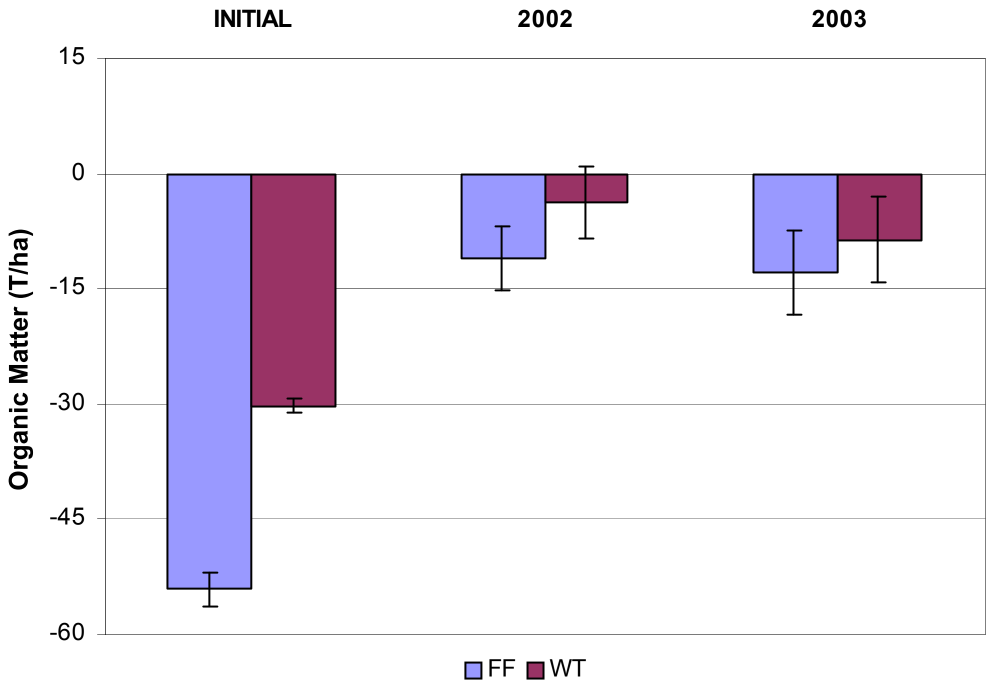


Figure 6.3b: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Tarawera

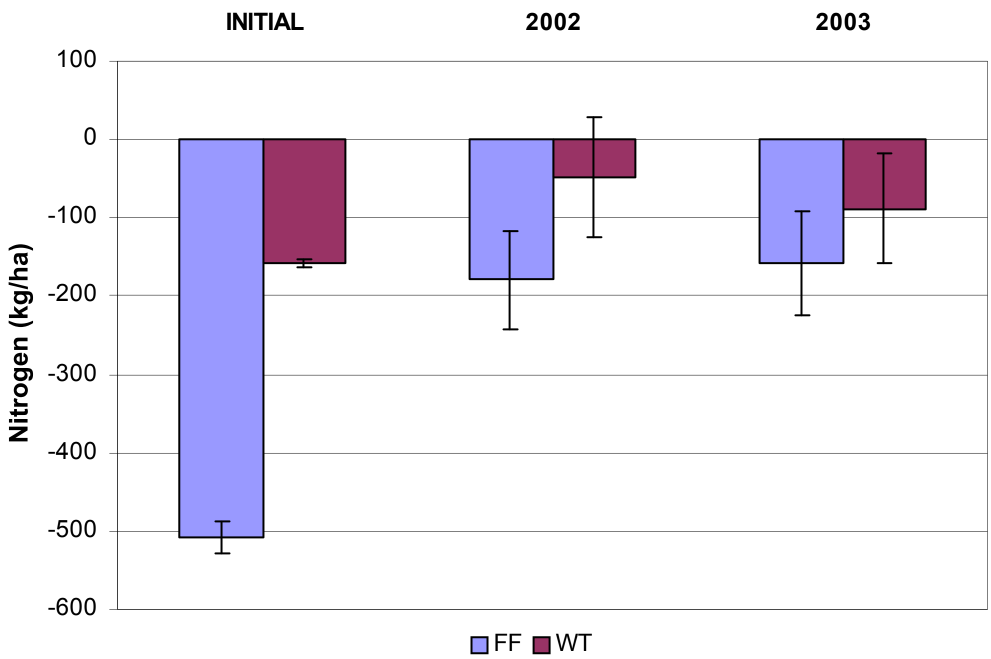


Figure 6.4a: Effects of WT Treatment on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Berwick

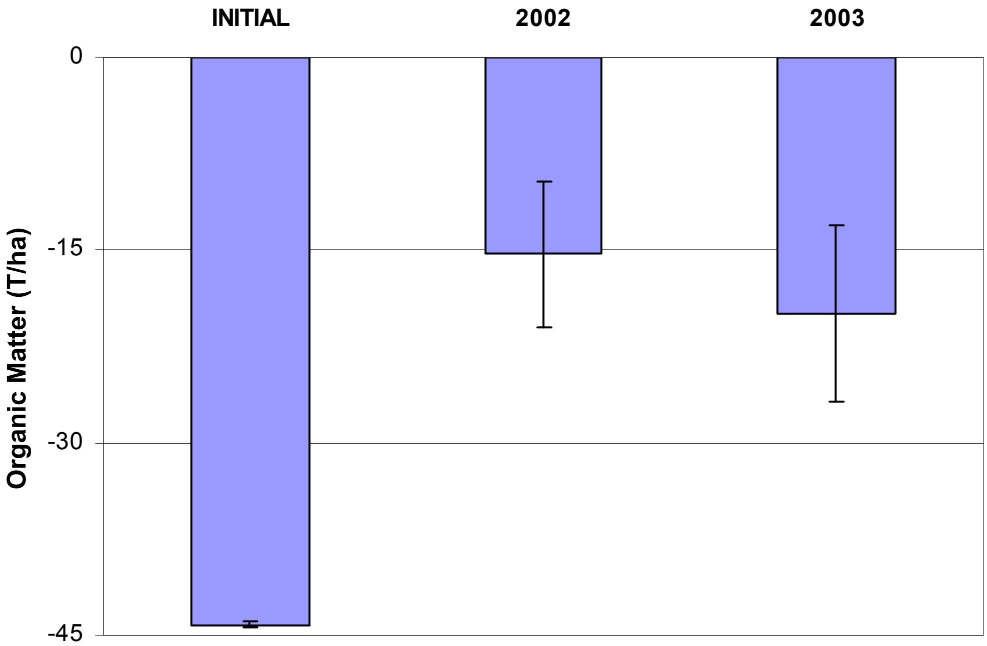


Figure 6.4b: Effects of WT Treatment on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Berwick

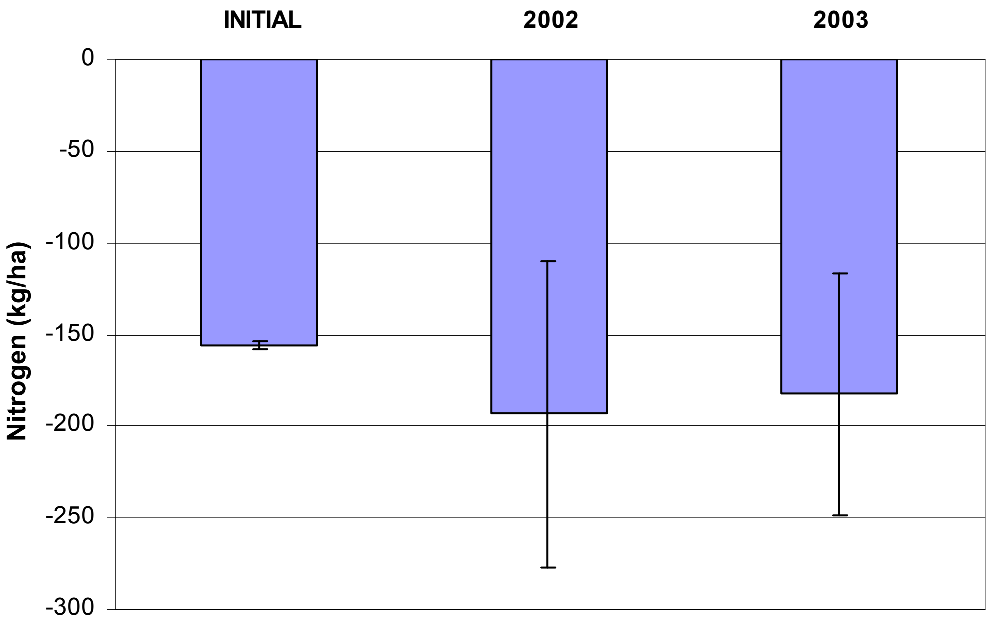


Figure 6.5a: Effects of WT Treatment on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Burnham

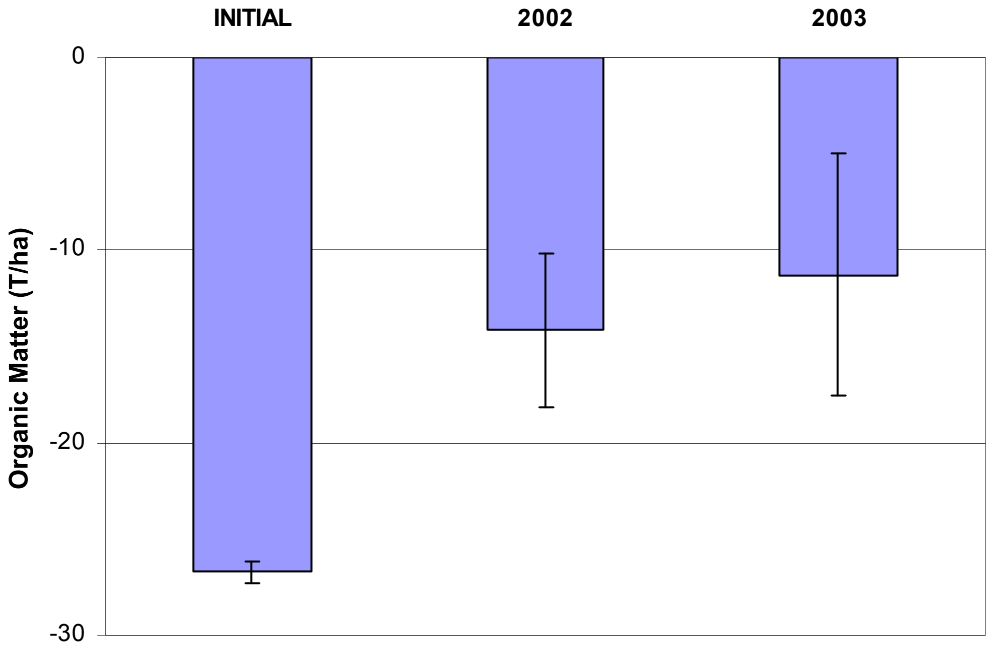


Figure 6.5b: Effects of WT Treatment on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Burnham

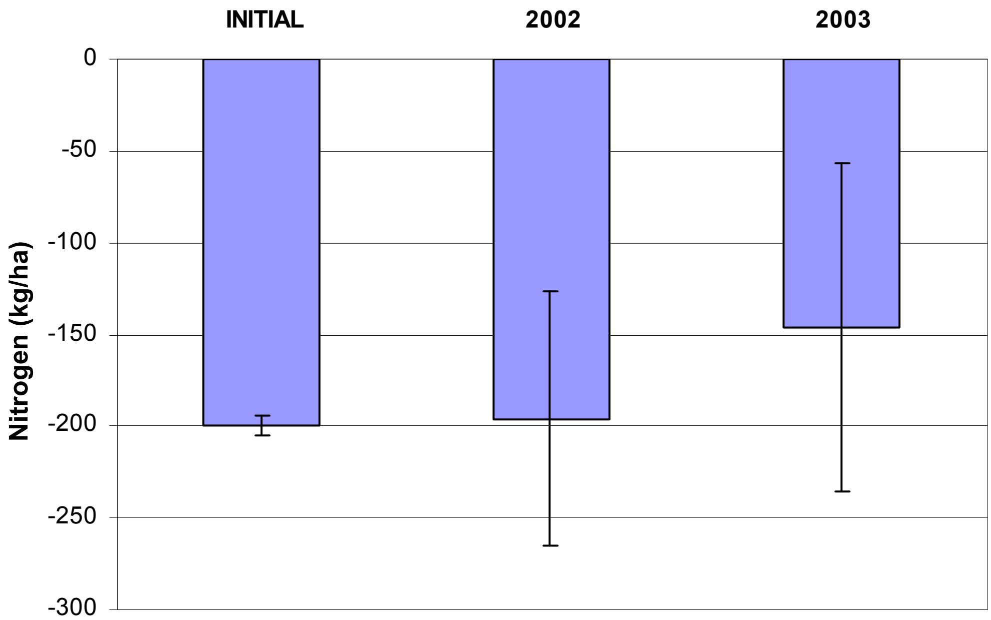


Figure 6.6a: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Kinleith

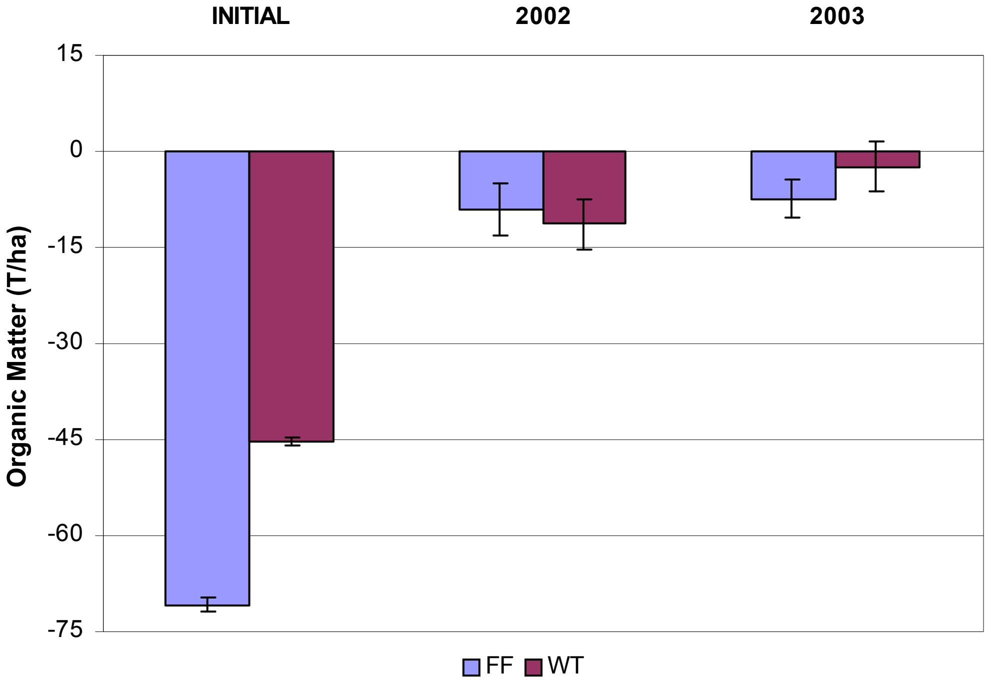


Figure 6.6b: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Kinleith

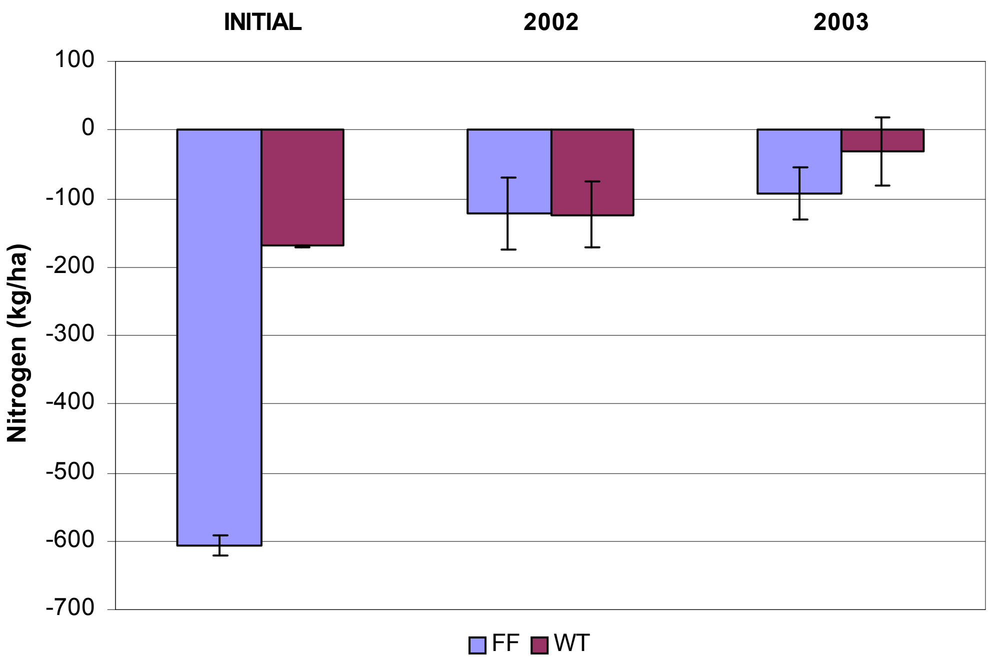


Figure 6.7a: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Organic Matter Relative to the SO Treatment at Golden Downs

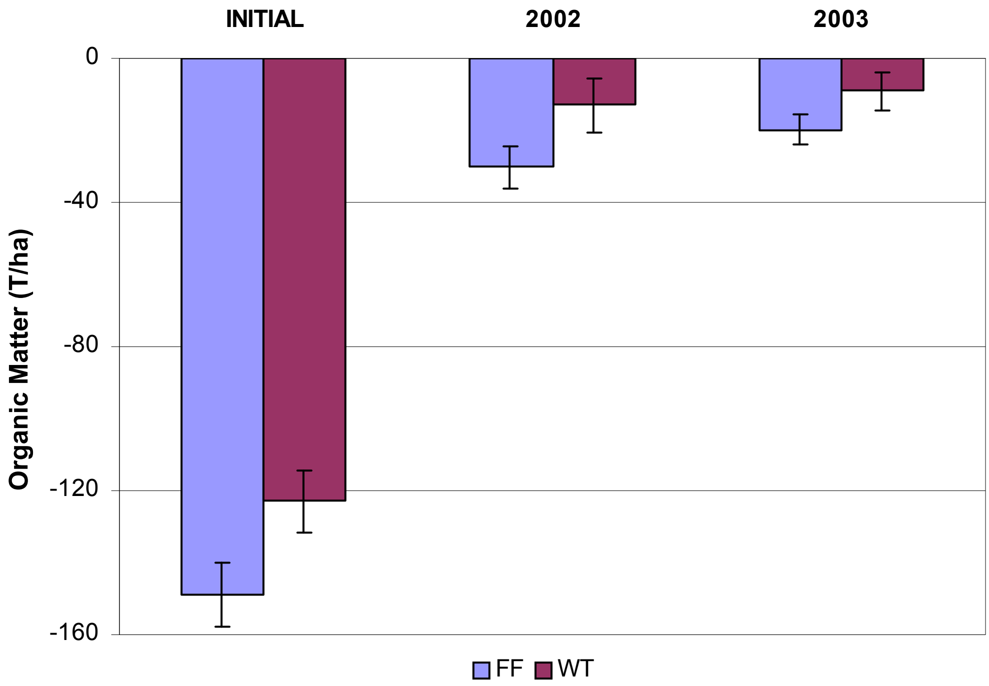
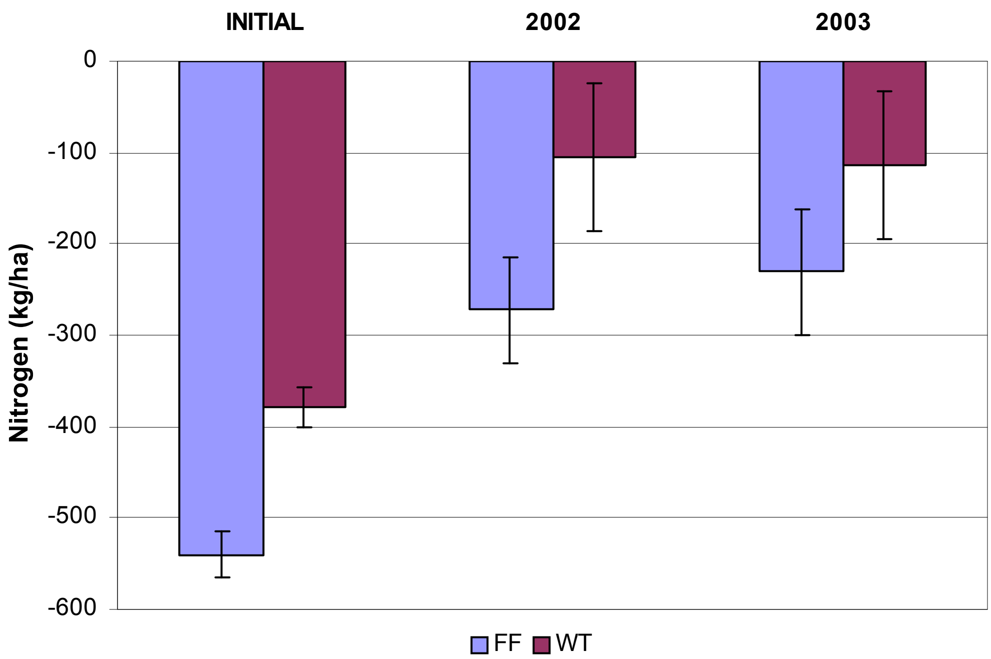


Figure 6.7b: Effects of WT and FF Treatments on the Absolute Mass of Forest Floor Nitrogen Relative to the SO Treatment at Golden Downs



The figures presented above indicate that although there were still several significant differences between the different levels of the organic matter removal treatments at the different sites in 2002 and 2003, in the majority of cases the differences in the mass of organic matter and nitrogen on the forest floor and have decreased with time. This suggests that there may be a degree of resilience to the organic matter removal treatments, or that these characteristics of the forest floor environment have settled at a new state, as illustrated in Figure 6.1. This cannot be confirmed, however, without additional sampling work over the life of the trial, as more data points are required to accurately assess the direction of the trends in FH litter mass, nitrogen mass and all of the other parameters measured in Chapter Two.

Furthermore, it may also be possible that if the long-term trends at the sites do indicate that the parameters of the FH litter and soil environment in the different organic matter removal treatment plots are converging to a common value, the length of time taken for this to occur may exceed the life span of the rotation. Consequently, even if the parameters of the forest floor environment were converging to common values, the system could not be considered to be resilient, as a return to the pre-disturbance state had not yet occurred. Additionally, if the same organic matter removal treatments were repeated during the harvest of the current rotation, the differences between the treatment plots would be increased again.

Similar plots cannot be constructed for the effects of fertilisation on the various parameters of the physical and chemical environment of the forest floor in the LTSP sites, due to the lack of data immediately preceding and following the disturbance. Additionally, as the fertilised plots received nitrogen additions on a regular basis over the life of the trials, any effects of fertilisation in the treatment plots were being consistently reinforced, thereby confounding attempts to determine if the characteristics of the FH litter and soil were returning to the pre-disturbance state, settling at a new “steady state” or diverging from the conditions in the undisturbed, unfertilised plots. Based on the results presented in Chapter Two and Chapter Five regarding the effects of fertilisation on the FH litter and soil parameters and litter production, it is evident that there were still significant differences between the fertilised and unfertilised plots, but for the reasons given above, it was not possible to comprehensively determine if the differences induced by fertiliser addition were decreasing, remaining constant or increasing.

Overall, although there is some evidence to suggest that two of the parameters may be resilient to the organic matter removal treatments, there are still significant differences in the physical and chemical environment of the different fertilisation and organic matter removal treatment plots, and these differences have persisted over the life of all the trials to date. This indicates that these disturbances to the physical and chemical environment of the forest floor are long-lasting, and the effects of the disturbance may persist over the life of the current rotation, and into the next rotation. Furthermore, site based variability in the magnitude and persistence of the effects of the treatments on the physical and chemical environment reinforces the importance of site specificity in the development of sustainable management practices (Fox, 2000; Burger, 2002).

Resilience of the Microbial Community

As with the physical and chemical environment, the continued effects of the fertilisation and organic matter removal treatments on the parameters used to examine the FH litter and soil microbial communities in the different treatment plots has important implications regarding the sensitivity to disturbance and resilience of the microbial communities (Groffman and Bohlen, 1999; Klein and Paschke, 2000; van Bruggen and Semenov, 2000; Westergaard *et al.*, 2001). Based on the results presented in Chapters Three and Four, the microbial communities were found to be sensitive to the alterations made to the physical and chemical environment by the different treatment types in most cases, and this was reflected by the relationships between the parameters of the microbial community and environmental characteristics, such as moisture and nitrogen availability, which were altered by the fertilisation and organic matter removal treatments. These alterations to the habitat and selection pressures on the microbial communities (Ponder and Tadros, 2002) have overcome the level of tolerance to disturbance that was within the microbial community, and have resulted in measurable alterations.

As no data describing the conditions of the microbial communities in the different treatment plots at the LTSP sites was collected prior to the application of fertiliser or harvesting, and no microbial work was performed prior to this study, the resilience of the microbial community to the treatments can only be assessed based on the data collected over 2002 and 2003. There are inherent complications in attempting to accurately assess the long-term trends in the response of the microbial communities to the treatments based on a temporally limited set of data, and this is exacerbated by the variable nature of microbial communities. As discussed in Chapters Three and Four, the characteristics of the microbial community in the FH litter and soil cannot be considered as fixed values, and must be considered to be in a state of flux, constantly responding and adapting to environmental stimuli and selection pressures (Wardle, 1992, 1998a; Leckie, 2005). Consequently, microbiological data collected in 2002 and 2003 represent a series of "snapshots", describing aspects of the microbial communities in the at given points in time, and definitive statements regarding the long-term resilience of the microbial community cannot be made.

Furthermore, with regard to the persistence of the effects of the different organic matter removal treatments, several other studies have concluded that the soil microbial community is either relatively resilient to this form of disturbance (Niemelä and Sundman, 1977; Busse *et al*., 2006), or tolerant, displaying no significant responses (Chow *et al*., 2002; Li *et al*., 2004). These findings do not support those advanced in this study, which tend to indicate that the community is not tolerant, and if it is resilient to the treatment effects, the return to the pre-disturbance state will take a substantial period of time. However, it must be noted that variations in the methodology used to assess the parameters of the microbial community complicates direct comparisons to other studies, and differences in the time frame of the studies further exacerbates this situation.

Despite the general disagreement with the results of other studies, the statistical relationships that were found between the parameters of the physical and chemical environment and the microbial communities at several of the LTSP sites allow some general deductions to be made. The persistence of the effects of the treatments on the parameters of the physical and chemical environment that were statistically related to the parameters used to describe the microbial communities in the FH litter and soil suggests that the alterations to the microbial community will also be persistent. The variation in selection pressures on the microbial communities in the different treatment plots have not returned to equivalent states, as discussed earlier, and consequently may be acting to maintain the differences in the microbial community parameters detected when measured in 2002 and 2003 (Ponder and Tadros, 2002), and potentially beyond the life of the current rotation. Without further measurements and analysis over the life of the trial, this cannot be definitively proven, however. Consequently, the only unqualified statement that can be made at this time is that when measured in 2002 and 2003, there were significant variations in microbial community structure in the different treatment plots, and these variations were related to the effects of the fertilisation and organic matter removal treatments, which had persisted for up to 17 years.

With regard to the effects of the FF organic matter removal treatment on the FH litter microbial community, it could also be argued that the concept of sensitivity and resilience to the treatments was not the most appropriate way of considering the effects of the FF treatment on the FH litter microbial community. In this treatment type, the entire FH litter layer, and the microbial community inhabiting the litter, was removed from the treatment plots. Consequently, the relative differences in the FH litter microbial communities that were sampled in the FF treatment plots in 2002 and 2003 may be better considered as the product of several years successional development of a totally new microbial community, rather than the response of initially similar communities to variations in selection pressures. This may also explain why the differences in the microbial parameters between the WT and SO treatment plots tended to be less extreme than those between FF treatment plots and the two other organic matter removal treatments examined in Chapters Three and Four. However, as the relevant literature tends to focus on the effects of forest floor removal on the soil microbial community, no supporting research is readily available to corroborate this theory. Consequently, further research examining the characteristics of the microbial community that colonises newly developing

FH litter layer immediately after the FF treatment is applied is required to conclusively characterise the effects of this treatment.

Ecological Implications

The results of this study have shown that soil properties and microbial community structure can be significantly altered by the forest management regimes. Consequently, the effects of forest management need to be considered carefully with regard to the commitments made by the New Zealand forestry industry to the terms of the Montreal Process (Anonymous, 1995), with particular regard to the preservation and maintenance of soil productive capacity and biodiversity. As this study has also determined that these management effects have the potential to be long-term, the importance of properly assessing how a forestry management practice may influence the physical, chemical and microbiological properties of a plantation takes on greater importance, as any management decisions may influence these properties for many years.

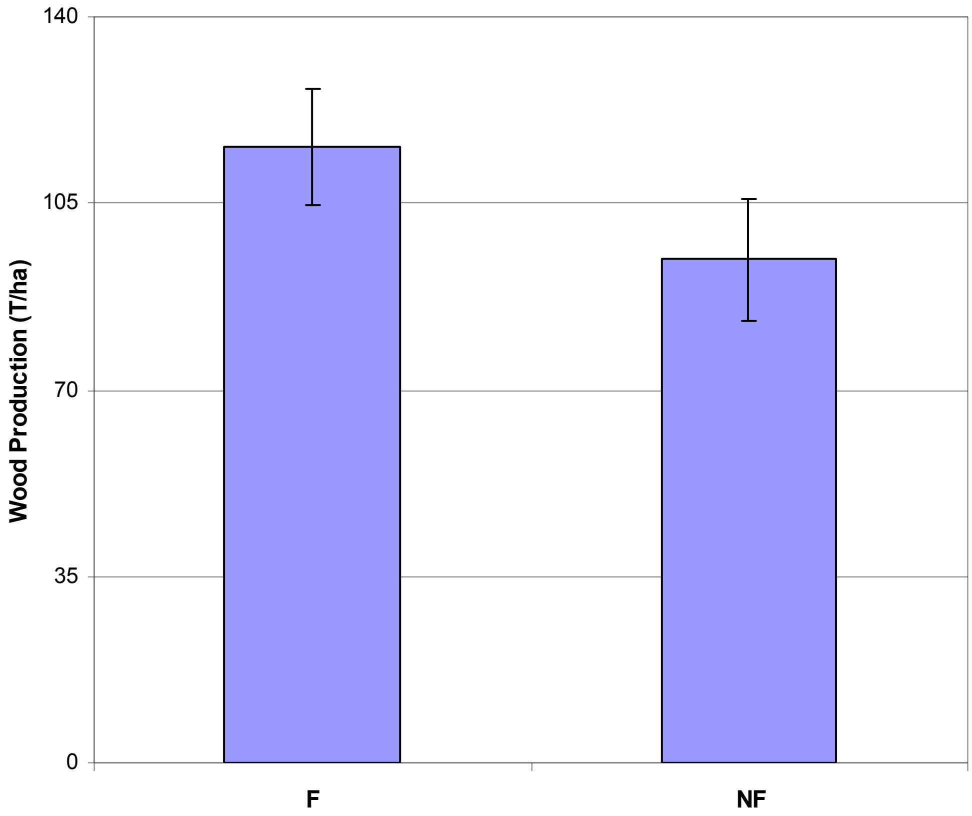
Implications for the Sustainability of Productivity

Prior to any discussion regarding the relationship between alterations to the FH litter and soil microbial community and the sustainability of productive capacity in plantation forestry, several factors that have the potential to effect productivity need to be addressed. In successive rotations on the same site, variations in productivity related to the capacity of the site to sustain tree growth may be prevented from becoming evident by the utilisation of modern silvicultural and genetic techniques (Burger, 2002). Although pools of available nutrients and other soil or microbiological characteristics may be negatively influenced by management practises over successive rotations or the life of a single rotation, increased nutrient use efficiency in genetically enhanced trees may render these differences unimportant to productive capacity, and techniques such as improved weed control reduce the demand for nutrients at the site, masking the effects of reduced nutrient availability on productivity at a given site.

However, unless the long-term effects of forestry practices on the capacity of a site to support tree growth over successive rotations are managed effectively, it is reasonable to assume that productivity will eventually be negatively affected. Silvicultural and genetic improvements cannot be relied on to continually improve as the site characteristics related to productivity deteriorate, and additionally the intensity of the silvicultural practices required to maintain productivity may also become financially non-viable.

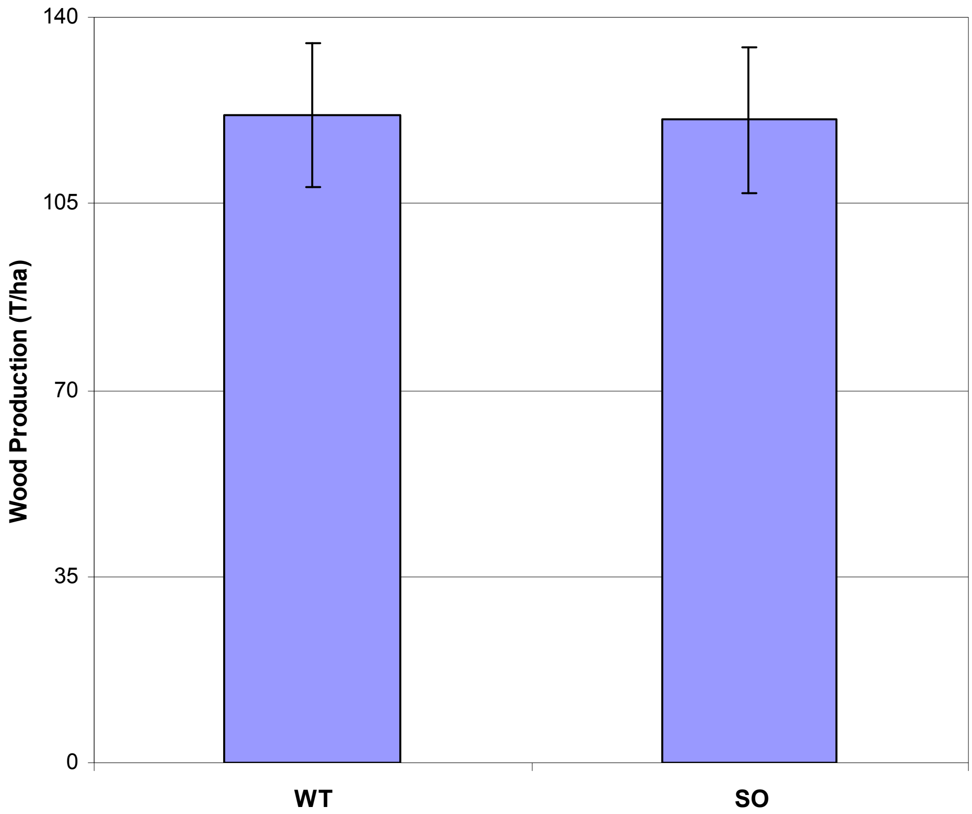
The effects of the fertilisation and organic matter removal treatments on the productive capacity of the LTSP sites was assessed by comparing the mass of wood harvested from the sites in the previous rotation to the predicted mass of wood produced at the sites in the different treatment plots over the same length of rotation, based on the 300 Index values for annual growth increments. The results of these comparisons are presented in Figures 6.8 – 6.10.

Figure 6.8: Effect of Fertilisation on Predicted Productivity of Second Rotation relative to the First Rotation at all Sites



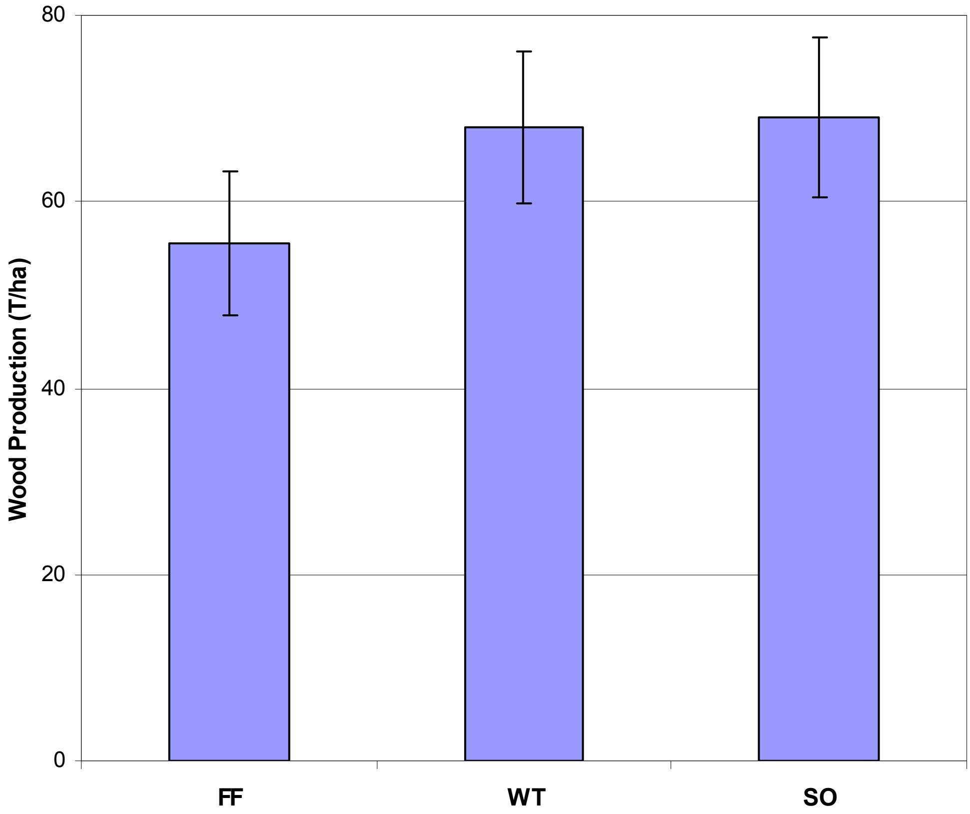
As discussed in Chapter Five, the addition of fertiliser significantly increased the mean estimated productivity capacity across all of the LTSP sites, but both fertilised and unfertilised plots were predicted to produce a substantially greater mass of wood than was produced across all sites in the previous rotation. This suggests that better management may have increased the productive capacity in the plots, such as improved thinning and pruning regimes, or more effective weed control.

Figure 6.9: Effects of Organic Matter Removal on Predicted Productivity of Second Rotation relative to the First Rotation at all Sites



As shown in Figure 6.9, there was no significant difference in the increase in estimated productive capacity of WT and SO treatment plots across all six LTSP sites. When compared to the previous rotation, the predicted productivity at the sites during the current rotation sites was substantially increased, and as with the fertilised and unfertilised plots in Figure 6.8, this increase was ostensibly the result of improved management practices at the sites.

Figure 6.10: Effects of Organic Matter Removal on Predicted Productivity of Second Rotation relative to the First Rotation at Woodhill, Tarawera, Kinleith and Golden Downs only



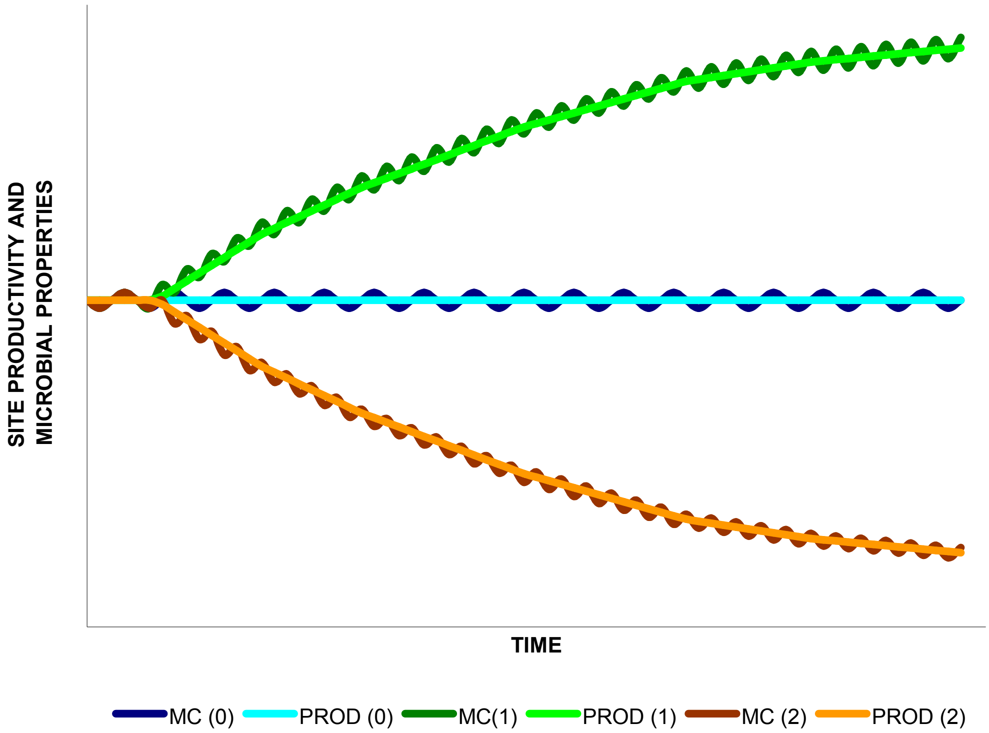
The effects of the organic matter removal treatments presented in Figure 6.10 are somewhat different to those in Figure 6.9. The mean predicted productivity in the FF treatment plots across Woodhill, Tarawera, Kinleith and Golden Downs is lower than that in the WT and SO treatment plots, although it must be noted that standard errors in these figures are large. Furthermore, although the mean predicted values for the WT and SO treatments have increased relative to the previous rotation, the magnitude of the increase is substantially lower than in Figure 6.9, suggesting that the increase in estimated productivity at Berwick and Burnham is substantially greater than that at the four other sites.

Overall these predicted mean values strongly indicate that the capacity of the sites to support wood production has been increased by the techniques employed in the establishment and management of the current rotation, but also that some conventional forestry management practices, such as whole tree harvesting combined with forest floor removal (FF organic matter removal treatment) have the potential to negatively influence the productive capacity of a site when compared to other levels of organic matter removal. The economic ramifications of these findings are immediately apparent. Alterations to the productive capacity of a site have a significant bearing on the profitability of forestry operations, although it must be noted that other factors that were not investigated in the study, such as wood quality, also influence the value of the wood produced at a site. Additionally, the longevity of the organic matter removal treatment effects in particular suggest that the profitability of future rotations at the LTSP sites may continue to be influenced, with or without further reinforcement during the harvest of the current rotation.

Potential Influence of the Microbial Community on Productivity

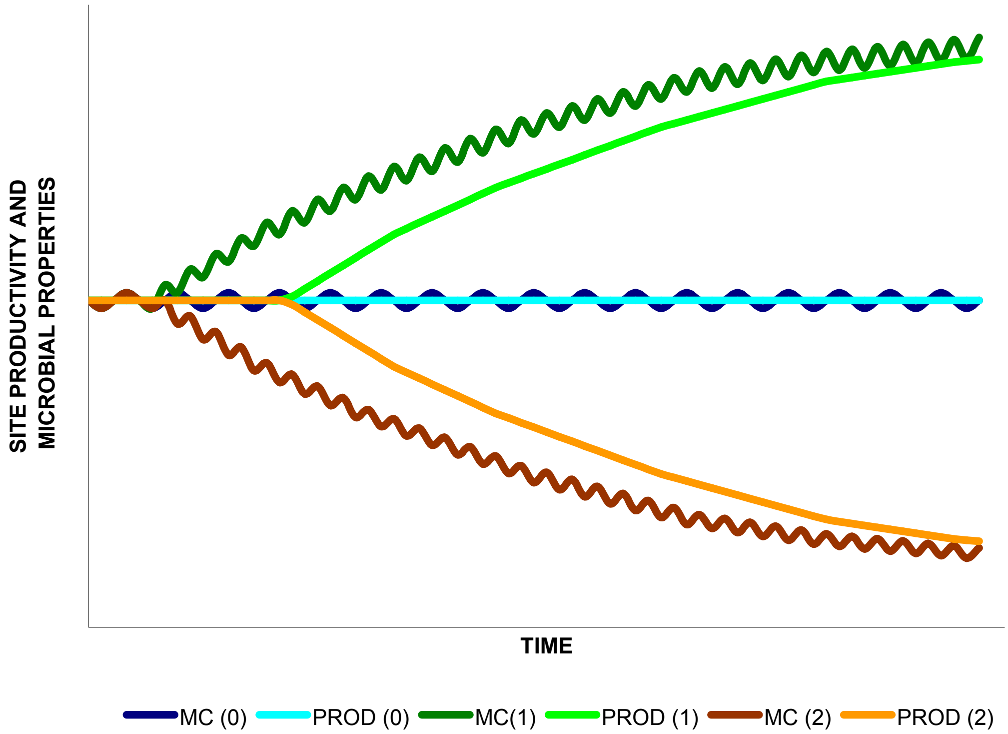
Although a substantial proportion of the significant differences in estimated productivity between the different levels of the fertilisation and organic matter removal treatments at the LTSP sites was found to be related to the effects of the treatments of the physical and chemical parameters described in Chapter Two, parameters describing the microbiological characteristics of the LTSP sites were also found to be statistically related to estimated productivity in several cases. As discussed in Chapter Five, ascertaining the mechanisms by which this relationship was operating was beyond the scope of this study, but three simplified hypothetical pathways have been constructed to explain the potential nature of the relationships. These are illustrated in Figures 6.11 – 6.13.

Figure 6.11: Hypothetical Relationship Between Productivity and Microbial Properties I**:** Both driven independently but similarly by disturbance



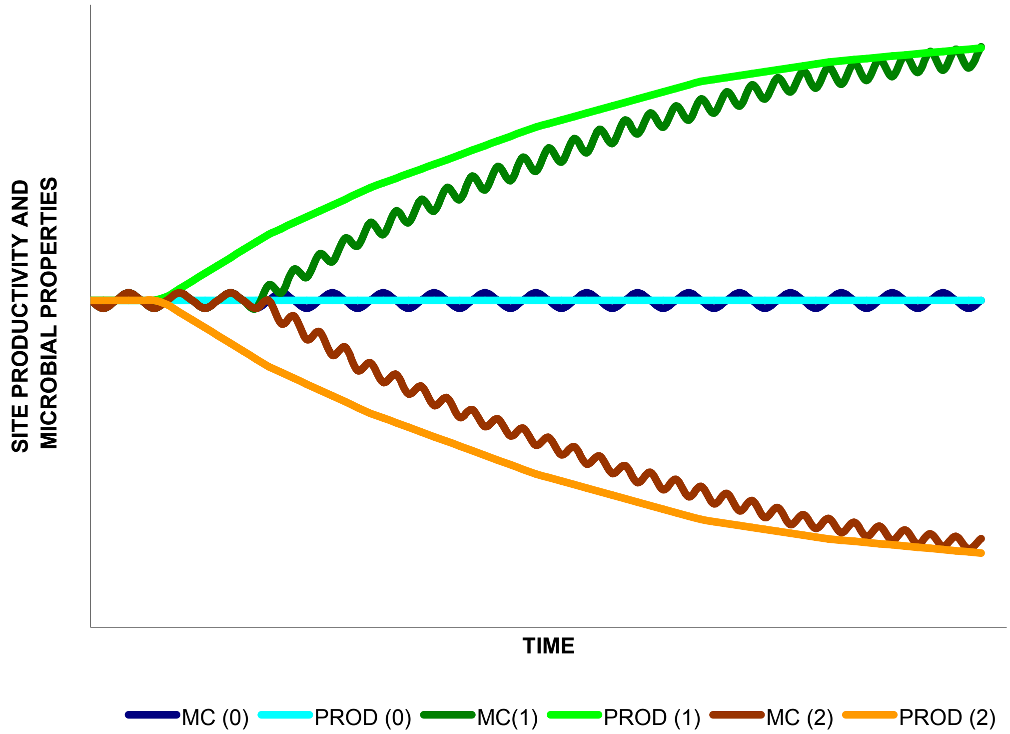
The first potential explanation for the statistical relationship between estimated productivity and microbial properties at the LTSP sites (Figure 6.11) proposes that after a disturbance occurs, the response of the microbial properties and site productivity to the disturbance is approximately uniform. Both are either unaffected (MC 0 and PROD 0), increased (MC 1 and PROD 1) or decreased (MC 2 and PROD 2), but the relationship between the two is based solely on the uniform response to the disturbance, rather than the response of one set of properties to the disturbance resulting in an alteration to the other.

Figure 6.12: Hypothetical Relationship Between Productivity and Microbial Properties II**:** Alterations to microbial properties influence site productivity



The second potential explanation for the relationship between estimated productivity and the parameters of the microbial community (Figure 6.12) describes the case where the application of disturbance results in a significant alteration the properties of the microbial community. This alteration, via mechanisms such as changes in the rate of nitrogen mineralisation, then induces an effect in the productive capacity of the site, which increases or decreases in response.

Figure 6.13: Hypothetical Relationship Between Productivity and Microbial Properties III**:** Alterations to site productivity influence microbial properties



The final hypothetical pathway for the relationship between the microbial community and site productivity (Figure 6.13) suggests that the disturbance may directly influence the productivity of the site, and this induces a response in the microbial community, which was otherwise unaffected by the disturbance.

All three of the models proposed above are intentionally simplistic, as the actual relationships between the parameters describing the FH litter and soil microbial community characteristics and the estimates of site productivity at the LTSP sites are most likely substantially more complicated, and may involve components of all three pathways.

6.3: OVERALL CONCLUSIONS

- Fertilisation regimes have significantly altered the physical and chemical properties of the forest floor environment at the six LTSP sites by increasing litter layer mass and nitrogen content.

- Significant differences between the different levels of the organic matter removal treatments applied at site establishment were still evident due to decreased litter layer mass, moisture content and nitrogen content in the forest floor environment up to 17 years later.

- The alterations to the physical and chemical environment caused by the fertilisation and organic matter removal treatments have induced alterations to FH litter and soil microbial community biomass, activity and diversity.

- The elapsed time since the application of the organic matter removal treatments strongly suggests that the effects on the physical, chemical and microbiological characteristics of the LTSP sites are persistent, and may continue for some time. A similar assessment of the long-term effects of the fertilisation treatment could not be made as this treatment has been reinforced over the life of the trial.

- Significant relationships between site productivity and the effects of the treatments on the physical, chemical and microbiological properties of the LTSP sites were determined, although the nature of the relationship between the properties of the microbial community and site productivity was unable to be determined.

6.4: RECOMMENDATIONS FOR FUTURE RESEARCH

Despite the inability of this study to identify the nature of the significant relationships between the parameters of the FH litter and soil microbial communities and productivity at the LTSP sites, the fact that these relationships have been detected at all indicates that understanding and incorporating the effects of forestry management practices on microbial community structure and function into sustainable forestry models is important for the long-term success of such models. Further research to identify the nature and specificity of the mechanisms responsible for the relationships is consequently required, and this research may also have important implications and applications for land management use strategies in other land based industries as well.

The utilisation of techniques based on the identification of nucleic acids can be used to more directly assess the genetic diversity of forest floor microbial communities in forest soils, and the relative impacts of management practices on those communities. Genetic techniques can also be used to generate information regarding the effects of management practices on the relative distribution and abundance of particular genes of interest within the microbial community, and this approach may establish a more tangible relationship between alterations to the properties of the microbial community and alterations to other site properties, such as productive capacity of the site.

The application of non-genetic molecular techniques may also have a major role in substantiating the relationship between land management practices, the microbial community and plant performance. The relative effects of different management strategies on the production and abundance of plant hormones synthesised and released by fungal and bacterial species in the microbial community can be assessed using techniques such as GC-MS, and this too may also provide a more direct understanding of the influence of the microbial community, and alterations to the microbial community, on wood production at a site. It is also possible that the relative abundance of these hormones may also have a bearing on tree form and wood quality, but this can only be considered as speculation.

The results of this thesis also suggest that it is important to investigate the impacts of disturbance and management practices on the characteristics of both the forest floor litter layer and the mineral soil. The analysis of the data generated in this study has determined that the parameters used to describe the FH litter environment can be statistically related to those describing the soil microbial community, and parameters describing the soil environment similarly have the potential to influence the characteristics of the FH litter microbial community. This suggests that a more inclusive approach, utilising a wider range of environmental parameters, may increase the understanding of how and why microbial communities respond to natural disturbances and management practices.

The most important consideration for future research into the relationships between forest floor properties, microbial communities, and productivity is not related to any particular technique, however, but is more to do with the nature of the research itself. The establishment of regularly monitored, long-term experiments, tracking the effects of management on all components of the forest system for the length of the rotation, and into subsequent rotations if practical, is critical to the accuracy of future research. The necessity for long-term experiments primarily relates to the inherently variable nature of the microbial community, and the sensitivity of the community to transient environmental stimuli. Any single measurement of parameters of the microbial community can only be considered as a "snapshot", and not necessarily representative of microbial community properties at other times. However, by acquiring as many of these "snapshots" as possible, accurately assessing the trends of the microbial community becomes more feasible, and allows the response of the community to disturbance over the short and long-term to be better understood. Furthermore, long-term experiments are the most appropriate way of assessing long-term effects on all components of the forest ecosystem, and this is fundamental to the development of effective sustainable land management practices.

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APPENDICES

Appendix One: Variation in rainfall at different sampling times

The rainfall levels at the six sites were compiled from data stored in the NIWA and Forest Protection Service databases. The total amount of rainfall that fell in the month of sampling is presented in the following table, as well as the total rainfall for that month and the two preceding months. The differences in rainfall between the 2002/2003 summer and winter sampling rounds (where applicable) are also given, and were calculated by subtracting the rainfall in 2003 from the rainfall in 2002.

Table A.1: Rainfall during and preceding sampling rounds

SITE	SAMPLING TIME	RAINFALL		2002 TO 2003 DIFFERENCES	
		SAMPLING MONTH (mm)	THREE MONTHS (mm)	SAMPLING MONTH (mm)	THREE MONTHS (mm)
WOODHILL	January 2002	68.2	325.8		
	August 2002	95.4	581.8		
	January 2003	87.6	252.8	19.4	-73.0
	August 2003	85.6	240.2	-9.8	-341.6
TARAWERA	January 2002	20.0	383.8		
	February 2003	38.4	177.8	18.4	-206.0
BERWICK	January 2002	134.4	290.3		
	August 2002	48.9	161.6		
	January 2003	78.4	225.4	-56.0	-64.9
	July 2003	32.1	124.7	-16.8	-36.9
BURNHAM	February 2002	66.8	302.1		
	January 2003	38.1	167.2	-28.7	-134.9
KINLEITH	January 2002	107.9	525.0		
	February 2003	25.4	291.9	-82.5	-233.1
GOLDEN DOWNS	February 2002	41.6	203.6		
	July 2002	20.6	233.2		
	February 2003	18.6	141.8	-23.0	-61.8
	August 2003	48.8	226.8	28.2	-6.4

In six of the nine comparisons between sampling months, more rain fell in 2002 than in 2003. For the three month totals, more rainfall was recorded in 2002 in every instance, indicating that 2002 was generally wetter than 2003 at all six sites.

Appendix Two: Mean Temperatures in Summer and Winter

The mean monthly temperatures for February and July at the six LTSP sites are presented in the following table. The three sites where sampling was carried out during winter are identified by italics. The data was calculated from temperature records from 1951-1980 maintained by the New Zealand Meteorological Service.

Table A.2: Mean Temperature at the LTSP sites

SITE	MEAN MONTHLY TEMPERATURE (^{0}C)	
	FEBRUARY (Summer)	JULY (Winter)
WOODHILL	18.9	*10.3*
TARAWERA	19.3	8.9
BERWICK	14.8	*5.1*
BURNHAM	16.6	6.0
KINLEITH	18.4	7.4
GOLDEN DOWNS	15.5	*4.6*

Strong seasonal variation was identified, as the temperatures in July were considerably less than those in February. Variation between the sites was also evident, but was not as substantial.

Appendix Three: FH mass and moisture content correlations

To determine if increased FH mass resulted in increased moisture content in the FH material and soil, the degree of correlation (r^2) between the values of these parameters was calculated. The r^2 values that were produced are given below in Table A.3. Negative correlations between FH mass and moisture content are indicated by the use of parentheses, and statistically significant correlations (at $\alpha = 0.05$) are in bold.

Table A.3: Correlation between FH and soil moisture content and FH mass

SITE	TIME	FH MASS: FH MOISTURE CONTENT CORRELATION	FH MASS: SOIL MOISTURE CONTENT CORRELATION
WOODHILL	Summer 2002	0.02	(0.10)
	Winter 2002	0.09	(0.00)
	Summer 2003	0.06	0.00
	Winter 2003	(0.11)	(0.18)
TARAWERA	Summer 2002	**0.26**	0.10
	Summer 2003	(0.15)	**0.19**
BERWICK	Summer 2002	**(0.47)**	0.00
	Winter 2002	(0.12)	0.09
	Summer 2003	**(0.33)**	(0.03)
	Winter 2003	(0.19)	(0.20)
BURNHAM	Summer 2002	**0.34**	0.12
	Summer 2003	**0.54**	0.07
KINLEITH	Summer 2002	(0.01)	0.12
	Summer 2003	**0.47**	0.01
GOLDEN DOWNS	Summer 2002	**0.38**	0.04
	Winter 2002	(0.00)	**0.18**
	Summer 2003	**0.43**	**0.27**
	Winter 2003	(0.01)	0.10

Several significant positive correlations were calculated between FH litter mass and moisture content in the summer sampling rounds, although none were found at Woodhill, and at Berwick the correlations were negative. Three significant correlations between FH litter mass and soil moisture content were found, and these were all positive.

Appendix Four: Variation in Microbial Biomass Technique

To address the concerns raised in the literature regarding the variability and reproducibility of the chloroform fumigation – extraction technique, a trial was conducted to determine if the masses of ammonium extracted from microbial tissue varied significantly between subsamples taken from a single sample. The details of the trial was as follows:

Samples of FH litter and soil were collected from within a $1m^2$ area from a site on the Ilam Campus of the University of Canterbury, and the FH litter and soil material was mixed in the laboratory. Twelve subsamples were taken from the each of the FH litter and soil samples, and the microbial biomass in each subsample was determined following the protocol described in Section 3.2, the results of which are present in Table A.4.

Table A.4: Microbial Biomass Estimates for Trial

Subsample #	FH Microbial Biomass (mg NH_4-N kg^{-1} FH)	Soil Microbial Biomass (mg NH_4-N kg^{-1} Soil)
1	73.1	32.8
2	80.3	29.9
3	72.5	30.8
4	77.2	29.8
5	74.6	31.5
6	78.6	30.7
7	75.2	31.5
8	79.1	30.1
9	77.0	29.1
10	74.9	30.6
11	75.1	31.1
12	75.6	30.9

The biomass data was then subjected to statistical analysis using a chi square (χ^2) distribution test to assess the variation in the results. The level of variability that was considered to be acceptable was a standard deviation of 5% or less of the mean, calculated with 95% confidence ($\alpha = 0.05$).

The test statistics for the FH litter and soil microbial biomass values (4.325 and 4.428 respectively) were both found to be less than critical χ^2 value of 4.575, so it could concluded that the standard deviation of the values when estimating biomass from the same sample was less than 5% of the mean with 95% confidence, fulfilling the criteria for the acceptance of this method.

Appendix Five: PLFA analysis of Soil Microbial Diversity in Summer 2002

To determine if the differences between the LTSP sites identified by the Principal Component Analysis of the Biolog data were replicated by another method of assessing microbial diversity, the phospholipid fatty acid profiles of the soil samples collected from each combination of treatments at each of the LTSP sites in Summer 2002 were determined. The method for the extraction and purification of the phospholipids was based on that described by Frostegard *et al.* (1991), and is summarised below.

Fresh soil samples were placed into glass centrifuge tubes, to which citrate buffer was added to make the total moisture content in the tubes 1.5ml. Chloroform, methanol and Bligh and Dyer solution (Bligh and Dyer, 1959) were added to the tubes, which were then vortexed and left to separate for 2 hours.

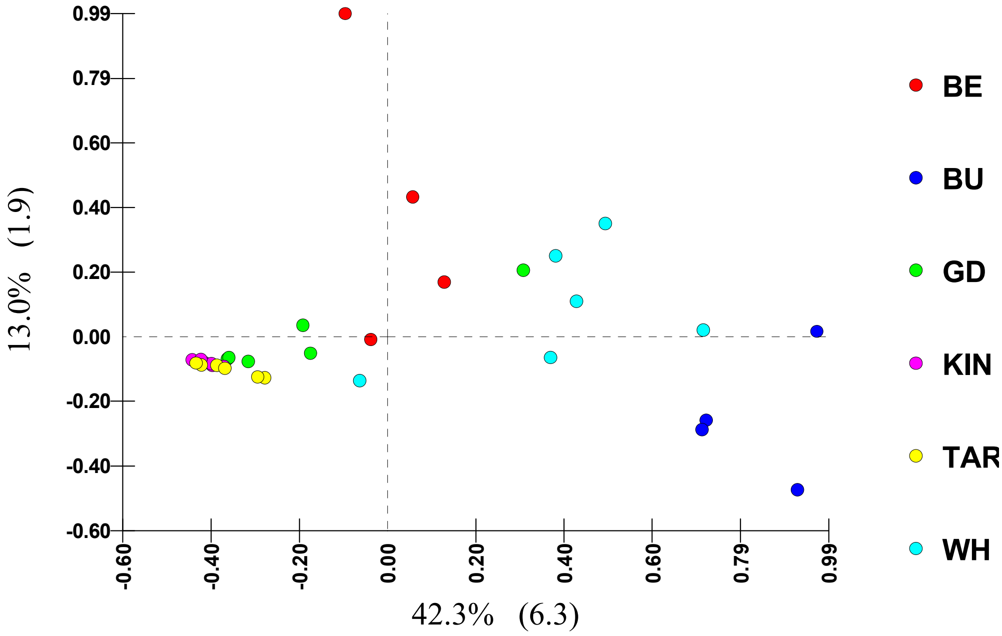
After 2 hours elapsed, the tubes were vortexed and centrifuged again. The supernatant was collected and transferred in to a second centrifuge tube, and the soil pellet in the first centrifuge tube was washed twice with Bligh and Dyer solution, which were which were added to the supernatant in the second centrifuge tube. Chloroform and citrate buffer were then added to the second centrifuge tube, which was vortexed and left for 12 hours to allow complete phase separation.

A sample of the lower chloroform phase was then transferred into a vial, and the chloroform was evaporated under a stream of nitrogen gas. The dried lipids inside the vial were dissolved with chloroform, and transferred to a Silic Acid sorbent column. Neutral lipids were eluted with chloroform, then discarded. Glycolipids were eluted with acetone, then discarded. Polar lipids were eluted in methanol, collected in centrifuge tubes, and evaporated under nitrogen gas.

Methyl ester standards were added to the tube, and the dried lipids were dissolved in methanol and toluene with vortexing. Potassium hydroxide, prepared in methanol, was then added to the tubes, and the tubes were incubated at $37^{o}C$ for 15 minutes in a water bath. Hexane, chloroform, acetic acid and ddH_2O were then added, and the tubes were centrifuged. The upper organic phase was transferred to a clean vial, the contents of the tube washed again with hexane, and the new upper organic phase in the tube added to the vial. The collected organic phase was evaporated under nitrogen gas.

The phospholipids in the sample were then dissolved in ethyl acetate and characterised using Gas chromatography mass spectrometry and an analytical software package. The differences between the PLFA profiles of the different sites were analysed using PCA, and the results of the analysis are presented in Figure A.1.

Figure A.1: Relative PLFA profiles at the LTSP sites



Based on the relative positions of the data points on the principal axis, it was determined that the bacterial community in the soil sample collected from Burnham were statistically different from all other sites, as was the community in the Woodhill soil samples. The community profile for Berwick was statistically different to all other sites with the exception of Golden Downs, and Golden Downs, Tarawera and Kinleith were all found to have similar soil bacterial communities, the latter two sites in particular.

STATISTICAL APPENDICES

The ANOVA outputs for the statistical analyses of the data presented in Chapters 2 – 5 are given in the following six sections. The page numbers for the each section, and the chapter to which the outputs are relevant, are as follows:

STATISTICAL APPENDIX ONE: Physical and Chemical ANOVA Outputs

1.1.1: WOODHILL SUMMER 2002

Woodhill FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.04018034	0.04018034	12.02458	0.0046511
HARV	2	0.00113355	0.00056677	0.16962	0.8459775
FERT:HARV	2	0.00726106	0.00363053	1.08649	0.3684004
Residuals	12	0.04009822	0.00334152		

Woodhill FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	16.57094	16.57094	4.71386	0.0506912
HARV	2	84.14768	42.07384	11.96854	0.0013862
FERT:HARV	2	6.54929	3.27464	0.93152	0.4206644
Residuals	12	42.18443	3.51537		

Woodhill FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	26370.58	26370.58	6.879275	0.0222680
HARV	2	1358.34	679.17	0.177174	0.8397855
FERT:HARV	2	773.94	386.97	0.100949	0.9047387
Residuals	12	46000.05	3833.34		

Woodhill FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	942.6563	942.6563	21.98907	0.0005239
HARV	2	244.6597	122.3299	2.85355	0.0968728
FERT:HARV	2	59.5936	29.7968	0.69506	0.5180599
Residuals	12	514.4317	42.8693		

Woodhill FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.013356	2.013356	62.95015	0.0000041
HARV	2	0.166011	0.083006	2.59528	0.1157041
FERT:HARV	2	0.023411	0.011706	0.36599	0.7009905
Residuals	12	0.383800	0.031983		

Woodhill mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	12.68401	12.68401	30.75863	0.0001266
HARV	2	14.65951	7.32976	17.77461	0.0002584
FERT:HARV	2	0.18324	0.09162	0.22218	0.8039901
Residuals	12	4.94847	0.41237		

Woodhill mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.02347222	0.02347222	51.52439	0.0000112
HARV	2	0.01333333	0.00666667	14.63415	0.0006045
FERT:HARV	2	0.00017778	0.00008889	0.19512	0.8252933
Residuals	12	0.00546667	0.00045556		

Woodhill FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	199.2399	199.2399	14.98852	0.0022218
HARV	2	23.7269	11.8635	0.89247	0.4351690
FERT:HARV	2	13.2192	6.6096	0.49723	0.6202094
Residuals	12	159.5141	13.2928		

Woodhill Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001363916	0.001363916	11.57667	0.0052459
HARV	2	0.000090473	0.000045237	0.38396	0.6892340
FERT:HARV	2	0.001464898	0.000732449	6.21689	0.0140328
Residuals	12	0.001413791	0.000117816		

Woodhill Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.7320500	0.7320500	34.88721	0.0000718
HARV	2	0.4550111	0.2275056	10.84220	0.0020442
FERT:HARV	2	0.0091000	0.0045500	0.21684	0.8081461
Residuals	12	0.2518000	0.0209833		

Woodhill Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.615604	0.6156037	5.344032	0.03935364
HARV	2	1.217937	0.6089684	5.286431	0.02257187
FERT:HARV	2	0.923862	0.4619311	4.010006	0.04637687
Residuals	12	1.382335	0.1151946		

Woodhill Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.002037671	0.002037671	6.141151	0.0290572
HARV	2	0.001701285	0.000850642	2.563674	0.1182897
FERT:HARV	2	0.002287913	0.001143956	3.447666	0.0656085
Residuals	12	0.003981672	0.000331806		

Woodhill Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	399.4031	399.4031	8.263685	0.0139684
HARV	2	136.4492	68.2246	1.411573	0.2814785
FERT:HARV	2	144.4959	72.2480	1.494817	0.2632337
Residuals	12	579.9879	48.3323		

1.1.2: WOODHILL SUMMER 2003

Woodhill FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00440463	0.004404631	2.623442	0.1312605
HARV	2	0.00127682	0.000638409	0.380243	0.6916467
FERT:HARV	2	0.00524319	0.002621594	1.561448	0.2496191
Residuals	12	0.02014741	0.001678951		

Woodhill FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	34.04837	34.04837	62.67658	0.0000042
HARV	2	0.41531	0.20765	0.38225	0.6903410
FERT:HARV	2	0.65828	0.32914	0.60589	0.5614626
Residuals	12	6.51887	0.54324		

Woodhill FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	50.534	50.534	0.206448	0.6576752
HARV	2	912.282	456.141	1.863490	0.1973402
FERT:HARV	2	3109.609	1554.804	6.351903	0.0131372
Residuals	12	2937.332	244.778		

Woodhill FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	12.9027	12.90270	0.8604790	0.3718868
HARV	2	23.7378	11.86892	0.7915362	0.4754440
FERT:HARV	2	19.5336	9.76678	0.6513448	0.5388287
Residuals	12	179.9374	14.99479		

Woodhill FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.7192602	0.7192602	47.91289	0.0000160
HARV	2	0.2352396	0.1176198	7.83514	0.0066528
FERT:HARV	2	0.0718039	0.0359020	2.39158	0.1336121
Residuals	12	0.1801420	0.0150118		

Woodhill mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	7.631022	7.631022	62.62351	0.0000042
HARV	2	0.045644	0.022822	0.18729	0.8315819
FERT:HARV	2	0.162711	0.081356	0.66764	0.5309760
Residuals	12	1.462267	0.121856		

Woodhill mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.008888889	0.008888889	80.00	0.0000012
HARV	2	0.000277778	0.000138889	1.25	0.3212769
FERT:HARV	2	0.000344444	0.000172222	1.55	0.2518986
Residuals	12	0.001333333	0.000111111		

Woodhill FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	724.860	724.8599	5.756207	0.0335670
HARV	2	655.594	327.7971	2.603080	0.1150758
FERT:HARV	2	333.861	166.9304	1.325616	0.3018857
Residuals	12	1511.120	125.9267		

Woodhill Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00032156	0.00032156	0.045713	0.8342886
HARV	2	0.09449519	0.04724760	6.716768	0.0110318
FERT:HARV	2	0.00096679	0.00048339	0.068720	0.9339528
Residuals	12	0.08441131	0.00703428		

1.1.3: WOODHILL WINTER 2002

```
Woodhill FH moisture content
          Df   Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.000677978 0.000677978 2.098854 0.1730326
     HARV  2 0.001037709 0.000518854 1.606247 0.2409267
FERT:HARV  2 0.002736658 0.001368329 4.236014 0.0405623
Residuals 12 0.003876274 0.000323023
Woodhill FH oven dry ash free mass
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  32.78158 32.78158 49.04659 0.0000143
     HARV  2   1.96389  0.98194  1.46915 0.2687081
FERT:HARV  2   0.60473  0.30237  0.45239 0.6465233
Residuals 12   8.02052  0.66838
Woodhill FH density
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  2211.145 2211.145 18.16094 0.0011044
     HARV  2   188.078   94.039  0.77238 0.4835708
FERT:HARV  2   244.141  122.071  1.00261 0.3956832
Residuals 12  1461.033  121.753
Woodhill Soil moisture content
          Df  Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.00304626 0.00304626 0.977489 0.3423363
     HARV  2 0.06076638 0.03038319 9.749418 0.0030572
FERT:HARV  2 0.00512138 0.00256069 0.821679 0.4629773
Residuals 12 0.03739692 0.00311641
```

1.1.4: WOODHILL WINTER 2003

```
Woodhill FH moisture content
          Df   Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.000147148 0.000147148 0.363874 0.5575922
     HARV  2 0.000689519 0.000344759 0.852534 0.4506096
FERT:HARV  2 0.002365918 0.001182959 2.925263 0.0922957
Residuals 12 0.004852728 0.000404394
Woodhill FH oven dry ash free mass
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  34.89671 34.89671 33.46509 0.0000868
     HARV  2   1.47975  0.73988  0.70952 0.5113959
FERT:HARV  2   0.05218  0.02609  0.02502 0.9753422
Residuals 12  12.51335  1.04278
Woodhill FH density
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
     FERT  1    117.18 117.1787 0.1387860 0.7159873
     HARV  2   1238.93 619.4639 0.7336910 0.5004819
FERT:HARV  2   1295.98 647.9900 0.7674772 0.4856761
Residuals 12  10131.74 844.3117
Woodhill Soil moisture content
          Df  Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.00973537 0.00973537 2.657565 0.1290081
     HARV  2 0.05745999 0.02872999 7.842722 0.0066310
FERT:HARV  2 0.00044091 0.00022046 0.060180 0.9418770
Residuals 12 0.04395922 0.00366327
```

1.1.5: WOODHILL SUMMER 2002 and 2003

Woodhill FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.1352513	0.1352513	53.87994	0.0000001
FERT	1	0.0355959	0.0355959	14.18029	0.0009505
HARV	2	0.0024025	0.0012012	0.47854	0.6254763
YEAR:FERT	1	0.0089891	0.0089891	3.58099	0.0705681
YEAR:HARV	2	0.0000079	0.0000039	0.00157	0.9984307
FERT:HARV	2	0.0092861	0.0046430	1.84964	0.1790241
YEAR:FERT:HARV	2	0.0032182	0.0016091	0.64101	0.5355428
Residuals	24	0.0602456	0.0025102		

Woodhill FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	293.2464	293.2464	144.5059	0.0000000
FERT	1	49.0628	49.0628	24.1772	0.0000513
HARV	2	48.1040	24.0520	11.8523	0.0002629
YEAR:FERT	1	1.5565	1.5565	0.7670	0.3898282
YEAR:HARV	2	36.4590	18.2295	8.9831	0.0012239
FERT:HARV	2	2.8607	1.4303	0.7048	0.5041317
YEAR:FERT:HARV	2	4.3469	2.1734	1.0710	0.3584731
Residuals	24	48.7033	2.0293		

Woodhill FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	28963.50	28963.50	14.20436	0.0009429
FERT	1	14364.94	14364.94	7.04489	0.0138861
HARV	2	898.46	449.23	0.22031	0.8038719
YEAR:FERT	1	12056.17	12056.17	5.91262	0.0228679
YEAR:HARV	2	1372.16	686.08	0.33647	0.7176040
FERT:HARV	2	957.39	478.70	0.23476	0.7925524
YEAR:FERT:HARV	2	2926.16	1463.08	0.71753	0.4981301
Residuals	24	48937.38	2039.06		

Woodhill FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	2722.186	2722.186	94.08896	0.0000000
FERT	1	588.065	588.065	20.32572	0.0001450
HARV	2	155.173	77.587	2.68168	0.0888925
YEAR:FERT	1	367.494	367.494	12.70198	0.0015722
YEAR:HARV	2	113.224	56.612	1.95673	0.1632189
FERT:HARV	2	70.897	35.449	1.22524	0.3114108
YEAR:FERT:HARV	2	8.230	4.115	0.14223	0.8681474
Residuals	24	694.369	28.932		

Woodhill FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1.187662	1.187662	50.5440	0.0000002
FERT	1	2.569689	2.569689	109.3597	0.0000000
HARV	2	0.371932	0.185966	7.9143	0.0022919
YEAR:FERT	1	0.162927	0.162927	6.9338	0.0145662
YEAR:HARV	2	0.029319	0.014659	0.6239	0.5443348
FERT:HARV	2	0.057335	0.028667	1.2200	0.3128914
YEAR:FERT:HARV	2	0.037880	0.018940	0.8061	0.4583448
Residuals	24	0.563942	0.023498		

Woodhill mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	14.96400	14.96400	56.02106	0.0000001
FERT	1	19.99580	19.99580	74.85872	0.0000000
HARV	2	8.16980	4.08490	15.29273	0.0000522
YEAR:FERT	1	0.31922	0.31922	1.19509	0.2851572
YEAR:HARV	2	6.53536	3.26768	12.23328	0.0002174
FERT:HARV	2	0.33869	0.16934	0.63398	0.5391299
YEAR:FERT:HARV	2	0.00727	0.00363	0.01360	0.9864975
Residuals	24	6.41073	0.26711		

Woodhill mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.01913611	0.01913611	67.5392	0.0000000
FERT	1	0.03062500	0.03062500	108.0882	0.0000000
HARV	2	0.00847222	0.00423611	14.9510	0.0000607
YEAR:FERT	1	0.00173611	0.00173611	6.1275	0.0207597
YEAR:HARV	2	0.00513889	0.00256944	9.0686	0.0011656
FERT:HARV	2	0.00035000	0.00017500	0.6176	0.5475634
YEAR:FERT:HARV	2	0.00017222	0.00008611	0.3039	0.7407170
Residuals	24	0.00680000	0.00028333		

Woodhill FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	357.946	357.9458	5.14218	0.0326370
FERT	1	842.078	842.0776	12.09712	0.0019449
HARV	2	311.843	155.9216	2.23994	0.1282559
YEAR:FERT	1	82.022	82.0222	1.17832	0.2884827
YEAR:HARV	2	367.478	183.7390	2.63956	0.0920109
FERT:HARV	2	200.011	100.0055	1.43666	0.2574420
YEAR:FERT:HARV	2	147.069	73.5345	1.05638	0.3633294
Residuals	24	1670.634	69.6097		

WOODHILL SUMMER 2002 and 2003 continued

Woodhill Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.2153223	0.2153223	60.21241	0.0000001
FERT	1	0.0001805	0.0001805	0.05047	0.8241478
HARV	2	0.0456391	0.0228196	6.38123	0.0059935
YEAR:FERT	1	0.0015050	0.0015050	0.42085	0.5226719
YEAR:HARV	2	0.0489465	0.0244733	6.84367	0.0044483
FERT:HARV	2	0.0005102	0.0002551	0.07133	0.9313512
YEAR:FERT:HARV	2	0.0019215	0.0009608	0.26867	0.7666666
Residuals	24	0.0858251	0.0035760		

1.1.6: WOODHILL WINTER 2002 and 2003

Woodhill FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.001142014	0.001142014	3.139918	0.0890950
FERT	1	0.000096710	0.000096710	0.265899	0.6108140
HARV	2	0.001707759	0.000853879	2.347703	0.1171619
YEAR:FERT	1	0.000728416	0.000728416	2.002748	0.1698597
YEAR:HARV	2	0.000019469	0.000009734	0.026764	0.9736196
FERT:HARV	2	0.005084451	0.002542225	6.989735	0.0040546
YEAR:FERT:HARV	2	0.000018125	0.000009063	0.024918	0.9754156
Residuals	24	0.008729002	0.000363708		

Woodhill FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.25844	0.25844	0.30207	0.5876662
FERT	1	67.66176	67.66176	79.08311	0.0000000
HARV	2	3.31301	1.65650	1.93612	0.1661389
YEAR:FERT	1	0.01653	0.01653	0.01932	0.8906121
YEAR:HARV	2	0.13064	0.06532	0.07634	0.9267221
FERT:HARV	2	0.22330	0.11165	0.13050	0.8782771
YEAR:FERT:HARV	2	0.43361	0.21680	0.25340	0.7782068
Residuals	24	20.53387	0.85558		

Woodhill FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	16754.18	16754.18	34.68542	0.0000045
FERT	1	655.14	655.14	1.35632	0.2556233
HARV	2	272.89	136.45	0.28248	0.7563861
YEAR:FERT	1	1673.18	1673.18	3.46391	0.0750155
YEAR:HARV	2	1154.12	577.06	1.19466	0.3201826
FERT:HARV	2	721.86	360.93	0.74722	0.4843845
YEAR:FERT:HARV	2	818.26	409.13	0.84700	0.4411156
Residuals	24	11592.77	483.03		

Woodhill Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0059801	0.00598014	1.76414	0.1966026
FERT	1	0.0118366	0.01183659	3.49178	0.0739282
HARV	2	0.1167750	0.05838752	17.22427	0.0000230
YEAR:FERT	1	0.0009450	0.00094504	0.27879	0.6023460
YEAR:HARV	2	0.0014513	0.00072566	0.21407	0.8088163
FERT:HARV	2	0.0038763	0.00193816	0.57176	0.5720363
YEAR:FERT:HARV	2	0.0016860	0.00084299	0.24868	0.7818140
Residuals	24	0.0813561	0.00338984		

1.1.7: WOODHILL SUMMER and WINTER (2002 and 2003)

Woodhill FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0557685	0.0557685	38.8097	0.0000001
SEASON	1	0.2605371	0.2605371	181.3098	0.0000000
FERT	1	0.0197017	0.0197017	13.7105	0.0005500
HARV	2	0.0040664	0.0020332	1.4149	0.2528968
YEAR:SEASON	1	0.0806248	0.0806248	56.1074	0.0000000
YEAR:FERT	1	0.0074176	0.0074176	5.1620	0.0276064
SEASON:FERT	1	0.0159909	0.0159909	11.1282	0.0016470
YEAR:HARV	2	0.0000054	0.0000027	0.0019	0.9981192
SEASON:HARV	2	0.0000439	0.0000219	0.0153	0.9848578
FERT:HARV	2	0.0131029	0.0065514	4.5592	0.0153875
YEAR:SEASON:FERT	1	0.0022999	0.0022999	1.6005	0.2119374
YEAR:SEASON:HARV	2	0.0000219	0.0000110	0.0076	0.9923950
YEAR:FERT:HARV	2	0.0013881	0.0006940	0.4830	0.6199009
SEASON:FERT:HARV	2	0.0012677	0.0006338	0.4411	0.6459161
YEAR:SEASON:FERT:HARV	2	0.0018482	0.0009241	0.6431	0.5301350
Residuals	48	0.0689746	0.0014370		

Woodhill FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	138.0468	138.0468	95.7036	0.0000000
SEASON	1	109.8501	109.8501	76.1557	0.0000000
FERT	1	115.9789	115.9789	80.4046	0.0000000
HARV	2	29.6203	14.8101	10.2674	0.0001941
YEAR:SEASON	1	155.4581	155.4581	107.7743	0.0000000
YEAR:FERT	1	0.9469	0.9469	0.6565	0.4218116
SEASON:FERT	1	0.7457	0.7457	0.5169	0.4756365
YEAR:HARV	2	20.4691	10.2345	7.0953	0.0019971
SEASON:HARV	2	21.7968	10.8984	7.5555	0.0014037
FERT:HARV	2	1.6826	0.8413	0.5832	0.5619891
YEAR:SEASON:FERT	1	0.6261	0.6261	0.4341	0.5131531
YEAR:SEASON:HARV	2	16.1205	8.0603	5.5879	0.0065814
YEAR:FERT:HARV	2	2.4901	1.2451	0.8632	0.4282689
SEASON:FERT:HARV	2	1.4014	0.7007	0.4858	0.6182174
YEAR:SEASON:FERT:HARV	2	2.2904	1.1452	0.7939	0.4579127
Residuals	48	69.2372	1.4424		

Woodhill FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	830.23	830.23	0.65837	0.4211426
SEASON	1	17120.43	17120.43	13.57638	0.0005815
FERT	1	4442.29	4442.29	3.52271	0.0666190
HARV	2	962.29	481.15	0.38155	0.6848572
YEAR:SEASON	1	44887.45	44887.45	35.59544	0.0000003
YEAR:FERT	1	2373.34	2373.34	1.88204	0.1764809
SEASON:FERT	1	10577.80	10577.80	8.38812	0.0056718
YEAR:HARV	2	605.58	302.79	0.24011	0.7874799
SEASON:HARV	2	209.06	104.53	0.08289	0.9205821
FERT:HARV	2	1143.33	571.67	0.45333	0.6382030
YEAR:SEASON:FERT	1	11356.02	11356.02	9.00524	0.0042614
YEAR:SEASON:HARV	2	1920.69	960.35	0.76155	0.4725014
YEAR:FERT:HARV	2	2464.17	1232.08	0.97703	0.3837859
SEASON:FERT:HARV	2	535.92	267.96	0.21249	0.8093241
YEAR:SEASON:FERT:HARV	2	1280.25	640.13	0.50762	0.6051239
Residuals	48	60530.15	1261.04		

Woodhill Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0747673	0.0747673	21.46670	0.0000278
SEASON	1	0.0619743	0.0619743	17.79367	0.0001085
FERT	1	0.0074702	0.0074702	2.14478	0.1495745
HARV	2	0.1509805	0.0754902	21.67427	0.0000002
YEAR:SEASON	1	0.1465352	0.1465352	42.07224	0.0000000
YEAR:FERT	1	0.0000324	0.0000324	0.00931	0.9235390
SEASON:FERT	1	0.0045469	0.0045469	1.30548	0.2588817
YEAR:HARV	2	0.0213296	0.0106648	3.06201	0.0560308
SEASON:HARV	2	0.0114337	0.0057169	1.64139	0.2043968
FERT:HARV	2	0.0008584	0.0004292	0.12322	0.8843459
YEAR:SEASON:FERT	1	0.0024176	0.0024176	0.69413	0.4088907
YEAR:SEASON:HARV	2	0.0290682	0.0145341	4.17294	0.0213353
YEAR:FERT:HARV	2	0.0003005	0.0001503	0.04314	0.9578123
SEASON:FERT:HARV	2	0.0035281	0.0017641	0.50649	0.6057932
YEAR:SEASON:FERT:HARV	2	0.0033070	0.0016535	0.47474	0.6249369
Residuals	48	0.1671812	0.0034829		

1.2.1: TARAWERA SUMMER 2002

Tarawera FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00617607	0.006176071	4.566820	0.0465759
HARV	2	0.00516204	0.002581019	1.908503	0.1771316
FERT:HARV	2	0.00064924	0.000324619	0.240035	0.7890780
Residuals	18	0.02434282	0.001352379		

Tarawera FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	8.982935	8.982935	17.13817	0.0006152
HARV	2	5.069265	2.534632	4.83572	0.0208529
FERT:HARV	2	0.611164	0.305582	0.58301	0.5684160
Residuals	18	9.434663	0.524148		

Tarawera FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	372.702	372.7024	1.183951	0.2909082
HARV	2	149.356	74.6779	0.237227	0.7912397
FERT:HARV	2	218.591	109.2953	0.347195	0.7112971
Residuals	18	5666.317	314.7954		

Tarawera FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	175.8611	175.8611	10.24137	0.0049602
HARV	2	209.7560	104.8780	6.10763	0.0094497
FERT:HARV	2	63.2385	31.6193	1.84136	0.1872522
Residuals	18	309.0895	17.1716		

Tarawera FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.7561500	0.7561500	67.51339	0.0000002
HARV	2	0.2503583	0.1251792	11.17671	0.0006991
FERT:HARV	2	0.0318250	0.0159125	1.42076	0.2673551
Residuals	18	0.2016000	0.0112000		

Tarawera mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.972267	1.972267	20.84971	0.0002394
HARV	2	1.224058	0.612029	6.47003	0.0076342
FERT:HARV	2	0.113308	0.056654	0.59892	0.5599931
Residuals	18	1.702700	0.094594		

Tarawera mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.002604167	0.002604167	26.40845	0.0000688
HARV	2	0.001458333	0.000729167	7.39437	0.0045283
FERT:HARV	2	0.000258333	0.000129167	1.30986	0.2943798
Residuals	18	0.001775000	0.000098611		

Tarawera FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	120.4774	120.4774	22.57446	0.0001595
HARV	2	1.9022	0.9511	0.17821	0.8382229
FERT:HARV	2	11.5256	5.7628	1.07980	0.3606737
Residuals	18	96.0640	5.3369		

Tarawera Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00094961	0.00094961	1.33681	0.2627133
HARV	2	0.02611513	0.01305756	18.38181	0.0000448
FERT:HARV	2	0.00022415	0.00011207	0.15777	0.8552124
Residuals	18	0.01278635	0.00071035		

Tarawera Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.520067	1.520067	14.38700	0.0013319
HARV	2	0.583300	0.291650	2.76038	0.0900303
FERT:HARV	2	0.229233	0.114617	1.08481	0.3590636
Residuals	18	1.901800	0.105656		

Tarawera Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	12.86348	12.86348	8.58425	0.0089480
HARV	2	46.99109	23.49555	15.67941	0.0001141
FERT:HARV	2	2.26523	1.13261	0.75583	0.4839533
Residuals	18	26.97295	1.49850		

Tarawera Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0661257	0.06612574	20.37107	0.0002689
HARV	2	0.1084546	0.05422732	16.70558	0.0000791
FERT:HARV	2	0.0016263	0.00081313	0.25050	0.7810819
Residuals	18	0.0584291	0.00324606		

Tarawera Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	118.7672	118.7672	19.76370	0.0003123
HARV	2	6.7182	3.3591	0.55898	0.5814068
FERT:HARV	2	51.1349	25.5674	4.25460	0.0306819
Residuals	18	108.1685	6.0094		

1.2.2: TARAWERA SUMMER 2003

Tarawera FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00263389	0.002633895	0.924424	0.3490550
HARV	2	0.00184110	0.000920548	0.323087	0.7280228
FERT:HARV	2	0.01078762	0.005393811	1.893078	0.1794018
Residuals	18	0.05128610	0.002849228		

Tarawera FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	10.53097	10.53097	19.36942	0.0003446
HARV	2	6.78502	3.39251	6.23977	0.0087373
FERT:HARV	2	2.16569	1.08285	1.99166	0.1654300
Residuals	18	9.78644	0.54369		

Tarawera FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	56.17	56.173	0.0502405	0.8251698
HARV	2	1987.37	993.684	0.8887482	0.4284604
FERT:HARV	2	1864.80	932.400	0.8339354	0.4504395
Residuals	18	20125.30	1118.072		

Tarawera FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.2221	1.22209	0.049132	0.8270756
HARV	2	43.8100	21.90500	0.880656	0.4316291
FERT:HARV	2	49.7959	24.89793	1.000982	0.3870782
Residuals	18	447.7231	24.87351		

Tarawera FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.2912566	0.2912566	13.19176	0.0019063
HARV	2	0.0897300	0.0448650	2.03205	0.1600574
FERT:HARV	2	0.0367361	0.0183680	0.83194	0.4512649
Residuals	18	0.3974161	0.0220787		

Tarawera mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.938017	1.938017	16.53363	0.0007248
HARV	2	1.366300	0.683150	5.82810	0.0111793
FERT:HARV	2	0.267633	0.133817	1.14162	0.3413637
Residuals	18	2.109900	0.117217		

Tarawera mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.002204167	0.002204167	21.73973	0.0001937
HARV	2	0.001058333	0.000529167	5.21918	0.0163047
FERT:HARV	2	0.000208333	0.000104167	1.02740	0.3779972
Residuals	18	0.001825000	0.000101389		

Tarawera FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	358.8794	358.8794	16.55357	0.0007209
HARV	2	16.1042	8.0521	0.37141	0.6949257
FERT:HARV	2	4.1720	2.0860	0.09622	0.9087291
Residuals	18	390.2377	21.6799		

Tarawera Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000325718	0.000325718	0.692392	0.4162556
HARV	2	0.008602504	0.004301252	9.143333	0.0018186
FERT:HARV	2	0.000225814	0.000112907	0.240011	0.7890967
Residuals	18	0.008467649	0.000470425		

1.2.3: TARAWERA SUMMER 2002 and 2003

Tarawera FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	2.003767	2.003767	953.8098	0.0000000
FERT	1	0.000372	0.000372	0.1769	0.6765107
HARV	2	0.001363	0.000682	0.3245	0.7249915
YEAR:FERT	1	0.008438	0.008438	4.0167	0.0526206
YEAR:HARV	2	0.005640	0.002820	1.3423	0.2740079
FERT:HARV	2	0.003115	0.001557	0.7414	0.4835938
YEAR:FERT:HARV	2	0.008322	0.004161	1.9806	0.1527327
Residuals	36	0.075629	0.002101		

Tarawera FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1.55556	1.55556	2.91348	0.0964553
FERT	1	19.48316	19.48316	36.49082	0.0000006
HARV	2	11.37038	5.68519	10.64803	0.0002329
YEAR:FERT	1	0.03075	0.03075	0.05759	0.8117029
YEAR:HARV	2	0.48390	0.24195	0.45316	0.6391923
FERT:HARV	2	0.50799	0.25399	0.47572	0.6252911
YEAR:FERT:HARV	2	2.26887	1.13443	2.12473	0.1342037
Residuals	36	19.22110	0.53392		

Tarawera FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	3545.61	3545.615	4.948978	0.0324640
FERT	1	359.13	359.129	0.501273	0.4835003
HARV	2	642.64	321.320	0.448499	0.6421055
YEAR:FERT	1	69.75	69.746	0.097352	0.7568313
YEAR:HARV	2	1494.09	747.043	1.042724	0.3628957
FERT:HARV	2	1038.99	519.493	0.725110	0.4912088
YEAR:FERT:HARV	2	1044.40	522.202	0.728890	0.4894274
Residuals	36	25791.61	716.434		

Tarawera FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	389.2891	389.2891	18.51767	0.0001233
FERT	1	73.8815	73.8815	3.51439	0.0689697
HARV	2	208.6749	104.3375	4.96312	0.0124839
YEAR:FERT	1	103.2017	103.2017	4.90909	0.0331268
YEAR:HARV	2	44.8910	22.4455	1.06769	0.3544387
FERT:HARV	2	72.7484	36.3742	1.73024	0.1916553
YEAR:FERT:HARV	2	40.2860	20.1430	0.95816	0.3931638
Residuals	36	756.8126	21.0226		

Tarawera FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0543276	0.0543276	3.26501	0.0791366
FERT	1	0.9929940	0.9929940	59.67749	0.0000000
HARV	2	0.3080218	0.1540109	9.25583	0.0005710
YEAR:FERT	1	0.0544127	0.0544127	3.27012	0.0789119
YEAR:HARV	2	0.0320666	0.0160333	0.96358	0.3911475
FERT:HARV	2	0.0640981	0.0320490	1.92610	0.1604366
YEAR:FERT:HARV	2	0.0044630	0.0022315	0.13411	0.8749292
Residuals	36	0.5990161	0.0166393		

Tarawera mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.052008	0.052008	0.49108	0.4879499
FERT	1	3.910208	3.910208	36.92165	0.0000005
HARV	2	2.551304	1.275652	12.04519	0.0000988
YEAR:FERT	1	0.000075	0.000075	0.00071	0.9789165
YEAR:HARV	2	0.039054	0.019527	0.18438	0.8323984
FERT:HARV	2	0.074029	0.037015	0.34951	0.7074023
YEAR:FERT:HARV	2	0.306913	0.153456	1.44899	0.2481747
Residuals	36	3.812600	0.105906		

Tarawera mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.000675000	0.000675000	6.75000	0.0134989
FERT	1	0.004800000	0.004800000	48.00000	0.0000000
HARV	2	0.002466667	0.001233333	12.33333	0.0000832
YEAR:FERT	1	0.000008333	0.000008333	0.08333	0.7744857
YEAR:HARV	2	0.000050000	0.000025000	0.25000	0.7801416
FERT:HARV	2	0.000150000	0.000075000	0.75000	0.4796033
YEAR:FERT:HARV	2	0.000316667	0.000158333	1.58333	0.2192532
Residuals	36	0.003600000	0.000100000		

Tarawera FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	588.4780	588.4780	43.56392	0.0000001
FERT	1	447.6131	447.6131	33.13596	0.0000015
HARV	2	13.4899	6.7450	0.49932	0.6110868
YEAR:FERT	1	31.7436	31.7436	2.34992	0.1340313
YEAR:HARV	2	4.5165	2.2583	0.16717	0.8467050
FERT:HARV	2	1.6479	0.8239	0.06100	0.9409249
YEAR:FERT:HARV	2	14.0497	7.0249	0.52004	0.5988966
Residuals	36	486.3017	13.5084		

TARAWERA SUMMER 2002 and 2003 continued

Tarawera Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.5643134	0.5643134	955.8336	0.0000000
FERT	1	0.0000815	0.0000815	0.1381	0.7123919
HARV	2	0.0321081	0.0160540	27.1923	0.0000001
YEAR:FERT	1	0.0011938	0.0011938	2.0221	0.1636333
YEAR:HARV	2	0.0026095	0.0013048	2.2100	0.1243670
FERT:HARV	2	0.0004119	0.0002059	0.3488	0.7078908
YEAR:FERT:HARV	2	0.0000381	0.0000191	0.0323	0.9682723
Residuals	36	0.0212540	0.0005904		

1.3.1: BERWICK SUMMER 2002

Berwick FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001026816	0.001026816	1.707436	0.2158065
HARV	1	0.003737637	0.003737637	6.215113	0.0282755
FERT:HARV	1	0.000000199	0.000000199	0.000332	0.9857708
Residuals	12	0.007216545	0.000601379		

Berwick FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	3.27092	3.270920	2.459558	0.1427908
HARV	1	9.37801	9.378014	7.051767	0.0209643
FERT:HARV	1	1.23058	1.230583	0.925333	0.3550623
Residuals	12	15.95858	1.329882		

Berwick FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	252.329	252.329	1.304601	0.2756532
HARV	1	1770.775	1770.775	9.155321	0.0105491
FERT:HARV	1	336.564	336.564	1.740116	0.2117418
Residuals	12	2320.978	193.415		

Berwick FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	5.8443	5.84431	0.4722426	0.5050220
HARV	1	3.6768	3.67681	0.2971002	0.5956916
FERT:HARV	1	1.5813	1.58131	0.1277757	0.7269574
Residuals	12	148.5077	12.37564		

Berwick FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.739600	0.7396000	29.23802	0.0001582
HARV	1	0.027225	0.0272250	1.07626	0.3199883
FERT:HARV	1	0.010000	0.0100000	0.39532	0.5412987
Residuals	12	0.303550	0.0252958		

Berwick mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.486506	0.486506	1.696955	0.2171319
HARV	1	2.037756	2.037756	7.107781	0.0205606
FERT:HARV	1	0.213906	0.213906	0.746114	0.4046442
Residuals	12	3.440325	0.286694		

Berwick mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.002500	0.002500000	13.95349	0.0028456
HARV	1	0.002025	0.002025000	11.30233	0.0056544
FERT:HARV	1	0.000100	0.000100000	0.55814	0.4693970
Residuals	12	0.002150	0.000179167		

Berwick FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1387.613	1387.613	25.54574	0.0002825
HARV	1	11.596	11.596	0.21347	0.6523241
FERT:HARV	1	0.810	0.810	0.01490	0.9048541
Residuals	12	651.825	54.319		

Berwick Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00097491	0.000974907	0.344769	0.5679728
HARV	1	0.00002883	0.000028826	0.010194	0.9212446
FERT:HARV	1	0.00295421	0.002954214	1.044737	0.3268869
Residuals	12	0.03393252	0.002827710		

Berwick Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0189062	0.0189062	0.245649	0.6291078
HARV	1	0.1242563	0.1242563	1.614460	0.2279473
FERT:HARV	1	0.0005063	0.0005063	0.006578	0.9366970
Residuals	12	0.9235750	0.0769646		

Berwick Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.04101	0.041006	0.0097294	0.9230545
HARV	1	3.37641	3.376406	0.8011067	0.3883634
FERT:HARV	1	0.55876	0.558756	0.1325739	0.7221129
Residuals	12	50.57613	4.214677		

Berwick Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00950625	0.00950625	1.563207	0.2350282
HARV	1	0.01625625	0.01625625	2.673176	0.1279938
FERT:HARV	1	0.00275625	0.00275625	0.453237	0.5135589
Residuals	12	0.07297500	0.00608125		

Berwick Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	11.12182	11.12182	3.119912	0.1027434
HARV	1	1.72416	1.72416	0.483665	0.5000137
FERT:HARV	1	0.36765	0.36765	0.103133	0.7536257
Residuals	12	42.77744	3.56479		

1.3.2: BERWICK SUMMER 2003

Berwick FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00107764	0.00107764	0.48965	0.4974240
HARV	1	0.02295908	0.02295908	10.43203	0.0072211
FERT:HARV	1	0.00204047	0.00204047	0.92714	0.3546107
Residuals	12	0.02640990	0.00220083		

Berwick FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	19.14709	19.14709	21.21273	0.0006049
HARV	1	15.86224	15.86224	17.57351	0.0012494
FERT:HARV	1	0.11371	0.11371	0.12598	0.7287980
Residuals	12	10.83147	0.90262		

Berwick FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2954.67	2954.673	2.267962	0.1579356
HARV	1	713.53	713.531	0.547695	0.4734921
FERT:HARV	1	808.40	808.405	0.620519	0.4461356
Residuals	12	15633.45	1302.788		

Berwick FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	3.08002	3.080025	0.369835	0.5544303
HARV	1	9.03002	9.030025	1.084283	0.3182669
FERT:HARV	1	3.74423	3.744225	0.449589	0.5152279
Residuals	12	99.93730	8.328108		

Berwick FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0430562	0.04305625	1.302515	0.2760184
HARV	1	0.0001563	0.00015625	0.004727	0.9463196
FERT:HARV	1	0.0039063	0.00390625	0.118170	0.7369762
Residuals	12	0.3966750	0.03305625		

Berwick mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4.505006	4.505006	28.47628	0.0001775
HARV	1	3.195156	3.195156	20.19668	0.0007342
FERT:HARV	1	0.004556	0.004556	0.02880	0.8680686
Residuals	12	1.898425	0.158202		

Berwick mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00140625	0.001406250	12.27273	0.0043558
HARV	1	0.00105625	0.001056250	9.21818	0.0103477
FERT:HARV	1	0.00000625	0.000006250	0.05455	0.8192712
Residuals	12	0.00137500	0.000114583		

Berwick FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	105.795	105.7954	0.7687293	0.3978232
HARV	1	28.725	28.7251	0.2087220	0.6559306
FERT:HARV	1	12.786	12.7865	0.0929088	0.7657331
Residuals	12	1651.485	137.6238		

Berwick Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00108891	0.001088911	0.7160019	0.4140141
HARV	1	0.00057201	0.000572010	0.3761195	0.5511349
FERT:HARV	1	0.00074400	0.000744003	0.4892112	0.4976138
Residuals	12	0.01824985	0.001520821		

1.3.3: BERWICK WINTER 2002

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Berwick FH moisture content
          Df  Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.00004816 0.000048162 0.048585 0.8292490
     HARV  1 0.00357334 0.003573341 3.604746 0.0819201
FERT:HARV  1 0.00157402 0.001574017 1.587851 0.2315876
Residuals 12 0.01189546 0.000991288
Berwick FH oven dry ash free mass
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   4.08184  4.08184 3.596432 0.0822311
     HARV  1  11.22367 11.22367 9.888956 0.0084582
FERT:HARV  1   0.00357  0.00357 0.003146 0.9561968
Residuals 12  13.61964  1.13497
Berwick FH density
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1408.896 1408.896 2.358341 0.1505512
     HARV  1  3321.085 3321.085 5.559138 0.0361970
FERT:HARV  1     0.397    0.397 0.000665 0.9798554
Residuals 12  7168.920  597.410
Berwick Soil moisture content
          Df  Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.00246240 0.002462400 2.530896 0.1376218
     HARV  1 0.00403416 0.004034155 4.146372 0.0644136
FERT:HARV  1 0.00442114 0.004421135 4.544116 0.0543905
Residuals 12 0.01167524 0.000972936
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1.3.4: BERWICK WINTER 2003

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Berwick FH moisture content
          Df  Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.00112874 0.001128736 1.281022 0.2798201
     HARV  1 0.00326685 0.003266846 3.707601 0.0781886
FERT:HARV  1 0.00071050 0.000710497 0.806356 0.3868624
Residuals 12 0.01057345 0.000881121
Berwick FH oven dry ash free mass
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  4.206860 4.206860 9.497680 0.0095055
     HARV  1  0.746450 0.746450 1.685234 0.2186267
FERT:HARV  1  0.056095 0.056095 0.126645 0.7281143
Residuals 12  5.315227 0.442936
Berwick FH density
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1    23.388   23.388 0.032785 0.8593383
     HARV  1  4761.473 4761.473 6.674538 0.0239423
FERT:HARV  1    40.958   40.958 0.057414 0.8146755
Residuals 12  8560.545  713.379
Berwick Soil moisture content
          Df  Sum of Sq     Mean Sq  F Value     Pr(F)
     FERT  1 0.00262337 0.002623372 2.182477 0.1653479
     HARV  1 0.00014149 0.000141495 0.117714 0.7374625
FERT:HARV  1 0.00199222 0.001992217 1.657396 0.2222316
Residuals 12 0.01442419 0.001202016
```

1.3.5: BERWICK SUMMER 2002 and 2003

Berwick FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.02261105	0.02261105	16.13805	0.0005045
FERT	1	0.00210415	0.00210415	1.50178	0.2322882
HARV	1	0.02261187	0.02261187	16.13864	0.0005044
YEAR:FERT	1	0.00000031	0.00000031	0.00022	0.9883144
YEAR:HARV	1	0.00408484	0.00408484	2.91545	0.1006412
FERT:HARV	1	0.00100016	0.00100016	0.71384	0.4065165
YEAR:FERT:HARV	1	0.00104050	0.00104050	0.74263	0.3973476
Residuals	24	0.03362645	0.00140110		

Berwick FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.82600	0.82600	0.73998	0.3981800
FERT	1	19.12283	19.12283	17.13128	0.0003706
HARV	1	24.81670	24.81670	22.23216	0.0000857
YEAR:FERT	1	3.29518	3.29518	2.95200	0.0986480
YEAR:HARV	1	0.42356	0.42356	0.37945	0.5436984
FERT:HARV	1	0.29807	0.29807	0.26703	0.6100602
YEAR:FERT:HARV	1	1.04622	1.04622	0.93726	0.3426384
Residuals	24	26.79005	1.11625		

Berwick FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	23419.49	23419.49	31.30524	0.0000093
FERT	1	2466.95	2466.95	3.29762	0.0818945
HARV	1	2366.21	2366.21	3.16295	0.0879991
YEAR:FERT	1	740.05	740.05	0.98924	0.3298520
YEAR:HARV	1	118.10	118.10	0.15786	0.6946442
FERT:HARV	1	50.87	50.87	0.06800	0.7964946
YEAR:FERT:HARV	1	1094.10	1094.10	1.46250	0.2383116
Residuals	24	17954.43	748.10		

Berwick FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	95.8074	95.80740	9.255076	0.0056123
FERT	1	0.2195	0.21945	0.021199	0.8854531
HARV	1	0.5913	0.59133	0.057123	0.8131318
YEAR:FERT	1	8.7049	8.70488	0.840899	0.3682634
YEAR:HARV	1	12.1155	12.11550	1.170368	0.2900764
FERT:HARV	1	0.2295	0.22950	0.022170	0.8828793
YEAR:FERT:HARV	1	5.0960	5.09603	0.492281	0.4896602
Residuals	24	248.4450	10.35188		

Berwick FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0148781	0.0148781	0.50994	0.4820514
FERT	1	0.2128781	0.2128781	7.29633	0.0124731
HARV	1	0.0116281	0.0116281	0.39855	0.5338059
YEAR:FERT	1	0.5697781	0.5697781	19.52897	0.0001819
YEAR:HARV	1	0.0157531	0.0157531	0.53993	0.4695798
FERT:HARV	1	0.0007031	0.0007031	0.02410	0.8779305
YEAR:FERT:HARV	1	0.0132031	0.0132031	0.45253	0.5075604
Residuals	24	0.7002250	0.0291760		

Berwick mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.515113	0.515113	2.31565	0.1411450
FERT	1	3.976200	3.976200	17.87475	0.0002958
HARV	1	5.168112	5.168112	23.23291	0.0000656
YEAR:FERT	1	1.015312	1.015312	4.56427	0.0430458
YEAR:HARV	1	0.064800	0.064800	0.29130	0.5943589
FERT:HARV	1	0.078012	0.078012	0.35070	0.5592555
YEAR:FERT:HARV	1	0.140450	0.140450	0.63138	0.4346358
Residuals	24	5.338750	0.222448		

Berwick mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.000028125	0.000028125	0.19149	0.6655927
FERT	1	0.003828125	0.003828125	26.06383	0.0000318
HARV	1	0.003003125	0.003003125	20.44681	0.0001401
YEAR:FERT	1	0.000078125	0.000078125	0.53191	0.4728612
YEAR:HARV	1	0.000078125	0.000078125	0.53191	0.4728612
FERT:HARV	1	0.000028125	0.000028125	0.19149	0.6655927
YEAR:FERT:HARV	1	0.000078125	0.000078125	0.53191	0.4728612
Residuals	24	0.003525000	0.000146875		

Berwick FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	146.666	146.666	1.52823	0.2283413
FERT	1	363.555	363.555	3.78817	0.0634147
HARV	1	38.411	38.411	0.40023	0.5329507
YEAR:FERT	1	1129.853	1129.853	11.77283	0.0021836
YEAR:HARV	1	1.910	1.910	0.01990	0.8889959
FERT:HARV	1	3.581	3.581	0.03731	0.8484620
YEAR:FERT:HARV	1	10.015	10.015	0.10436	0.7494585
Residuals	24	2303.310	95.971		

BERWICK SUMMER 2002 and 2003 continued

Berwick Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.02608432	0.02608432	11.99684	0.0020155
FERT	1	0.00000158	0.00000158	0.00072	0.9787467
HARV	1	0.00017201	0.00017201	0.07911	0.7809160
YEAR:FERT	1	0.00206224	0.00206224	0.94848	0.3398216
YEAR:HARV	1	0.00042883	0.00042883	0.19723	0.6609457
FERT:HARV	1	0.00333165	0.00333165	1.53231	0.2277391
YEAR:FERT:HARV	1	0.00036656	0.00036656	0.16859	0.6850097
Residuals	24	0.05218237	0.00217427		

1.3.6: BERWICK WINTER 2002 and 2003

Berwick FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.01048011	0.01048011	11.19425	0.0026930
FERT	1	0.00082161	0.00082161	0.87759	0.3581939
HARV	1	0.00683675	0.00683675	7.30263	0.0124398
YEAR:FERT	1	0.00035529	0.00035529	0.37950	0.5436688
YEAR:HARV	1	0.00000344	0.00000344	0.00367	0.9522004
FERT:HARV	1	0.00008474	0.00008474	0.09052	0.7661102
YEAR:FERT:HARV	1	0.00219977	0.00219977	2.34967	0.1383870
Residuals	24	0.02246891	0.00093620		

Berwick FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.17064	0.170640	0.21629	0.6460764
FERT	1	8.28823	8.288232	10.50536	0.0034755
HARV	1	8.87952	8.879523	11.25482	0.0026340
YEAR:FERT	1	0.00047	0.000471	0.00060	0.9807001
YEAR:HARV	1	3.09060	3.090599	3.91734	0.0593728
FERT:HARV	1	0.01568	0.015681	0.01988	0.8890608
YEAR:FERT:HARV	1	0.04398	0.043984	0.05575	0.8153468
Residuals	24	18.93487	0.788953		

Berwick FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	18435.22	18435.22	28.12844	0.0000193
FERT	1	534.62	534.62	0.81572	0.3754111
HARV	1	64.69	64.69	0.09870	0.7561044
YEAR:FERT	1	897.67	897.67	1.36966	0.2533610
YEAR:HARV	1	8017.87	8017.87	12.23365	0.0018530
FERT:HARV	1	16.64	16.64	0.02540	0.8747174
YEAR:FERT:HARV	1	24.71	24.71	0.03770	0.8476753
Residuals	24	15729.46	655.39		

Berwick Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.2724794	0.2724794	250.5613	0.0000000
FERT	1	0.0000013	0.0000013	0.0012	0.9729782
HARV	1	0.0028433	0.0028433	2.6146	0.1189523
YEAR:FERT	1	0.0050845	0.0050845	4.6755	0.0407829
YEAR:HARV	1	0.0013323	0.0013323	1.2251	0.2793265
FERT:HARV	1	0.0002389	0.0002389	0.2197	0.6435303
YEAR:FERT:HARV	1	0.0061745	0.0061745	5.6778	0.0254482
Residuals	24	0.0260994	0.0010875		

1.3.7: BERWICK SUMMER and WINTER (2002 and 2003)

Berwick FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.03193928	0.03193928	27.32999	0.0000037
SEASON	1	0.02778695	0.02778695	23.77689	0.0000123
FERT	1	0.00277771	0.00277771	2.37684	0.1297136
HARV	1	0.02715781	0.02715781	23.23855	0.0000148
YEAR:SEASON	1	0.00115187	0.00115187	0.98564	0.3257889
YEAR:FERT	1	0.00018824	0.00018824	0.16108	0.6899497
SEASON:FERT	1	0.00014805	0.00014805	0.12668	0.7234583
YEAR:HARV	1	0.00192568	0.00192568	1.64778	0.2054237
SEASON:HARV	1	0.00229082	0.00229082	1.96022	0.1679204
FERT:HARV	1	0.00083358	0.00083358	0.71329	0.4025452
YEAR:SEASON:FERT	1	0.00016736	0.00016736	0.14321	0.7067836
YEAR:SEASON:HARV	1	0.00216260	0.00216260	1.85050	0.1800794
YEAR:FERT:HARV	1	0.00010724	0.00010724	0.09176	0.7632600
SEASON:FERT:HARV	1	0.00025132	0.00025132	0.21505	0.6449325
YEAR:SEASON:FERT:HARV	1	0.00313304	0.00313304	2.68090	0.1080988
Residuals	48	0.05609536	0.00116865		

Berwick FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.87375	0.87375	0.91723	0.3430035
SEASON	1	27.20296	27.20296	28.55646	0.0000025
FERT	1	26.29499	26.29499	27.60332	0.0000034
HARV	1	31.69265	31.69265	33.26955	0.0000006
YEAR:SEASON	1	0.12289	0.12289	0.12900	0.7210424
YEAR:FERT	1	1.68724	1.68724	1.77119	0.1895224
SEASON:FERT	1	1.11607	1.11607	1.17160	0.2844798
YEAR:HARV	1	0.61294	0.61294	0.64344	0.4264214
SEASON:HARV	1	2.00357	2.00357	2.10326	0.1534892
FERT:HARV	1	0.22524	0.22524	0.23645	0.6289932
YEAR:SEASON:FERT	1	1.60841	1.60841	1.68844	0.2000133
YEAR:SEASON:HARV	1	2.90121	2.90121	3.04557	0.0873574
YEAR:FERT:HARV	1	0.33059	0.33059	0.34703	0.5585589
SEASON:FERT:HARV	1	0.08851	0.08851	0.09291	0.7618234
YEAR:SEASON:FERT:HARV	1	0.75962	0.75962	0.79742	0.3763226
Residuals	48	45.72492	0.95260		

Berwick FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	41705.79	41705.79	59.43131	0.0000000
SEASON	1	116.33	116.33	0.16577	0.6857120
FERT	1	2649.21	2649.21	3.77516	0.0578966
HARV	1	824.21	824.21	1.17451	0.2838912
YEAR:SEASON	1	148.92	148.92	0.21221	0.6471215
YEAR:FERT	1	3.80	3.80	0.00542	0.9416354
SEASON:FERT	1	352.36	352.36	0.50212	0.4819971
YEAR:HARV	1	5041.06	5041.06	7.18358	0.0100515
SEASON:HARV	1	1606.69	1606.69	2.28956	0.1368039
FERT:HARV	1	62.86	62.86	0.08957	0.7660146
YEAR:SEASON:FERT	1	1633.91	1633.91	2.32835	0.1335993
YEAR:SEASON:HARV	1	3094.90	3094.90	4.41028	0.0410032
YEAR:FERT:HARV	1	723.83	723.83	1.03147	0.3149069
SEASON:FERT:HARV	1	4.66	4.66	0.00664	0.9353958
YEAR:SEASON:FERT:HARV	1	394.98	394.98	0.56285	0.4567756
Residuals	48	33683.89	701.75		

Berwick Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.2335875	0.2335875	143.2287	0.0000000
SEASON	1	0.0417321	0.0417321	25.5889	0.0000066
FERT	1	0.0000000	0.0000000	0.0000	0.9982422
HARV	1	0.0008083	0.0008083	0.4956	0.4848214
YEAR:SEASON	1	0.0649762	0.0649762	39.8414	0.0000001
YEAR:FERT	1	0.0003352	0.0003352	0.2056	0.6523123
SEASON:FERT	1	0.0000028	0.0000028	0.0017	0.9668774
YEAR:HARV	1	0.0016364	0.0016364	1.0034	0.3215105
SEASON:HARV	1	0.0022070	0.0022070	1.3533	0.2504565
FERT:HARV	1	0.0008932	0.0008932	0.5477	0.4628793
YEAR:SEASON:FERT	1	0.0068115	0.0068115	4.1766	0.0464946
YEAR:SEASON:HARV	1	0.0001247	0.0001247	0.0765	0.7833348
YEAR:FERT:HARV	1	0.0017661	0.0017661	1.0829	0.3032612
SEASON:FERT:HARV	1	0.0026774	0.0026774	1.6417	0.2062512
YEAR:SEASON:FERT:HARV	1	0.0047750	0.0047750	2.9279	0.0935190
Residuals	48	0.0782818	0.0016309		

1.4.1: BURNHAM SUMMER 2002

Burnham FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00547886	0.00547886	4.288579	0.06059267
HARV	1	0.01059744	0.01059744	8.295146	0.01382727
FERT:HARV	1	0.00445201	0.00445201	3.484811	0.08654924
Residuals	12	0.01533056	0.00127755		

Burnham FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.296402	2.296402	3.50978	0.0855595
HARV	1	7.988925	7.988925	12.21015	0.0044281
FERT:HARV	1	0.073004	0.073004	0.11158	0.7441193
Residuals	12	7.851429	0.654286		

Burnham FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.421	0.4211	0.004524	0.9474796
HARV	1	671.824	671.8238	7.218809	0.0197872
FERT:HARV	1	675.881	675.8812	7.262406	0.0194929
Residuals	12	1116.789	93.0657		

Burnham FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	5.0738	5.07376	0.346191	0.5671871
HARV	1	71.3603	71.36026	4.869025	0.0475711
FERT:HARV	1	0.2678	0.26781	0.018273	0.8947128
Residuals	12	175.8716	14.65596		

Burnham FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.3875062	0.3875062	15.84758	0.0018233
HARV	1	0.0663062	0.0663062	2.71168	0.1255339
FERT:HARV	1	0.0150063	0.0150063	0.61370	0.4485839
Residuals	12	0.2934250	0.0244521		

Burnham mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.348100	0.348100	2.54731	0.1364661
HARV	1	1.525225	1.525225	11.16120	0.0058790
FERT:HARV	1	0.025600	0.025600	0.18733	0.6728216
Residuals	12	1.639850	0.136654		

Burnham mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00105625	0.001056250	6.417722	0.0262586
HARV	1	0.00140625	0.001406250	8.544304	0.0127674
FERT:HARV	1	0.00005625	0.000056250	0.341772	0.5696366
Residuals	12	0.00197500	0.000164583		

Burnham FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	237.6582	237.6582	9.059739	0.0108641
HARV	1	0.0058	0.0058	0.000222	0.9883609
FERT:HARV	1	7.6071	7.6071	0.289990	0.6000738
Residuals	12	314.7882	26.2324		

Burnham Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000004887	0.000004887	0.014157	0.9072588
HARV	1	0.001348023	0.001348023	3.904773	0.0715965
FERT:HARV	1	0.000000000	0.000000000	0.000000	0.9995632
Residuals	12	0.004142695	0.000345225		

Burnham Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.6280562	0.6280562	32.44721	0.0000997
HARV	1	0.0473063	0.0473063	2.44398	0.1439519
FERT:HARV	1	0.1207562	0.1207562	6.23862	0.0280323
Residuals	12	0.2322750	0.0193563		

Burnham Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4.80706	4.807056	2.012368	0.1814677
HARV	1	1.35141	1.351406	0.565736	0.4664561
FERT:HARV	1	0.24256	0.242556	0.101541	0.7554664
Residuals	12	28.66508	2.388756		

Burnham Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.030625	0.0306250	3.555878	0.0837689
HARV	1	0.004900	0.0049000	0.568940	0.4652251
FERT:HARV	1	0.000625	0.0006250	0.072569	0.7922086
Residuals	12	0.103350	0.0086125		

Burnham Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.79648	1.796483	2.148948	0.1683757
HARV	1	0.05626	0.056260	0.067298	0.7997088
FERT:HARV	1	0.00307	0.003069	0.003671	0.9526871
Residuals	12	10.03179	0.835982		

1.4.2: BURNHAM SUMMER 2003

Burnham FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.02626385	0.02626385	11.22744	0.0057723
HARV	1	0.00630395	0.00630395	2.69485	0.1266017
FERT:HARV	1	0.00000967	0.00000967	0.00413	0.9498013
Residuals	12	0.02807107	0.00233926		

Burnham FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	5.84194	5.841940	3.873460	0.0725970
HARV	1	5.10457	5.104567	3.384550	0.0906662
FERT:HARV	1	1.29940	1.299399	0.861558	0.3715973
Residuals	12	18.09836	1.508197		

Burnham FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2032.113	2032.113	3.306979	0.0940168
HARV	1	3191.697	3191.697	5.194039	0.0417504
FERT:HARV	1	490.981	490.981	0.799003	0.3889675
Residuals	12	7373.907	614.492		

Burnham FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	31.9790	31.97902	2.986200	0.1095973
HARV	1	2.5921	2.59210	0.242050	0.6316062
FERT:HARV	1	1.1236	1.12360	0.104922	0.7515774
Residuals	12	128.5073	10.70894		

Burnham FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0410063	0.04100625	0.5656522	0.4664885
HARV	1	0.0105062	0.01050625	0.1449263	0.7100854
FERT:HARV	1	0.0315063	0.03150625	0.4346064	0.5221875
Residuals	12	0.8699250	0.07249375		

Burnham mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.398306	1.398306	4.101983	0.0656655
HARV	1	1.150256	1.150256	3.374319	0.0910996
FERT:HARV	1	0.305256	0.305256	0.895481	0.3626626
Residuals	12	4.090625	0.340885		

Burnham mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00105625	0.001056250	3.992126	0.0688926
HARV	1	0.00105625	0.001056250	3.992126	0.0688926
FERT:HARV	1	0.00030625	0.000306250	1.157480	0.3031440
Residuals	12	0.00317500	0.000264583		

Burnham FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	21.451	21.4509	0.144028	0.7109399
HARV	1	48.985	48.9848	0.328899	0.5768981
FERT:HARV	1	150.296	150.2965	1.009138	0.3349366
Residuals	12	1787.226	148.9355		

Burnham Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000076314	0.000076314	0.198900	0.6635504
HARV	1	0.002683241	0.002683241	6.993426	0.0213949
FERT:HARV	1	0.000029253	0.000029253	0.076243	0.7871531
Residuals	12	0.004604166	0.000383681		

1.4.3: BURNHAM SUMMER 2002 and 2003

Burnham FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.8456603	0.8456603	467.6287	0.0000000
FERT	1	0.0278670	0.0278670	15.4098	0.0006359
HARV	1	0.0166242	0.0166242	9.1927	0.0057513
YEAR:FERT	1	0.0038757	0.0038757	2.1432	0.1561828
YEAR:HARV	1	0.0002772	0.0002772	0.1533	0.6988616
FERT:HARV	1	0.0024383	0.0024383	1.3483	0.2569921
YEAR:FERT:HARV	1	0.0020234	0.0020234	1.1189	0.3006913
Residuals	24	0.0434016	0.0018084		

Burnham FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	14.10181	14.10181	13.04224	0.0013974
FERT	1	7.73188	7.73188	7.15093	0.0132698
HARV	1	12.93267	12.93267	11.96095	0.0020415
YEAR:FERT	1	0.40646	0.40646	0.37592	0.5455615
YEAR:HARV	1	0.16082	0.16082	0.14874	0.7031399
FERT:HARV	1	0.99420	0.99420	0.91950	0.3471685
YEAR:FERT:HARV	1	0.37821	0.37821	0.34979	0.5597631
Residuals	24	25.94979	1.08124		

Burnham FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	4164.492	4164.492	11.77145	0.0021847
FERT	1	1045.519	1045.519	2.95529	0.0984712
HARV	1	3396.089	3396.089	9.59946	0.0049075
YEAR:FERT	1	987.015	987.015	2.78992	0.1078513
YEAR:HARV	1	467.432	467.432	1.32125	0.2616935
FERT:HARV	1	1159.491	1159.491	3.27744	0.0827773
YEAR:FERT:HARV	1	7.371	7.371	0.02084	0.8864318
Residuals	24	8490.696	353.779		

Burnham FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	998.7098	998.7098	78.74738	0.0000000
FERT	1	31.2643	31.2643	2.46516	0.1294875
HARV	1	50.5767	50.5767	3.98792	0.0572881
YEAR:FERT	1	5.7885	5.7885	0.45642	0.5057606
YEAR:HARV	1	23.3757	23.3757	1.84315	0.1872110
FERT:HARV	1	0.1472	0.1472	0.01160	0.9151158
YEAR:FERT:HARV	1	1.2443	1.2443	0.09811	0.7568176
Residuals	24	304.3788	12.6825		

Burnham FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.005000	0.0050000	0.103150	0.7508615
FERT	1	0.340313	0.3403125	7.020673	0.0140313
HARV	1	0.064800	0.0648000	1.336829	0.2589742
YEAR:FERT	1	0.088200	0.0882000	1.819573	0.1899549
YEAR:HARV	1	0.012013	0.0120125	0.247819	0.6231460
FERT:HARV	1	0.045000	0.0450000	0.928353	0.3448997
YEAR:FERT:HARV	1	0.001512	0.0015125	0.031203	0.8612705
Residuals	24	1.163350	0.0484729		

Burnham mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.969528	0.969528	4.06051	0.0552302
FERT	1	1.570878	1.570878	6.57905	0.0169952
HARV	1	2.662278	2.662278	11.14998	0.0027370
YEAR:FERT	1	0.175528	0.175528	0.73514	0.3997048
YEAR:HARV	1	0.013203	0.013203	0.05530	0.8160856
FERT:HARV	1	0.253828	0.253828	1.06307	0.3127960
YEAR:FERT:HARV	1	0.077028	0.077028	0.32260	0.5753227
Residuals	24	5.730475	0.238770		

Burnham mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0021125	0.002112500	9.84466	0.0044650
FERT	1	0.0021125	0.002112500	9.84466	0.0044650
HARV	1	0.0024500	0.002450000	11.41748	0.0024825
YEAR:FERT	1	0.0000000	0.000000000	0.00000	1.0000000
YEAR:HARV	1	0.0000125	0.000012500	0.05825	0.8113298
FERT:HARV	1	0.0003125	0.000312500	1.45631	0.2392786
YEAR:FERT:HARV	1	0.0000500	0.000050000	0.23301	0.6336749
Residuals	24	0.0051500	0.000214583		

Burnham FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	856.243	856.2428	9.776254	0.0045839
FERT	1	58.154	58.1545	0.663985	0.4231691
HARV	1	23.961	23.9614	0.273582	0.6057349
YEAR:FERT	1	200.955	200.9547	2.294424	0.1428996
YEAR:HARV	1	25.029	25.0292	0.285774	0.5978593
FERT:HARV	1	112.765	112.7649	1.287506	0.2677141
YEAR:FERT:HARV	1	45.139	45.1387	0.515377	0.4797509
Residuals	24	2102.015	87.5839		

BURNHAM SUMMER 2002 and 2003 continued

Burnham Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.07886418	0.07886418	216.3908	0.0000000
FERT	1	0.00002129	0.00002129	0.0584	0.8110766
HARV	1	0.00391749	0.00391749	10.7490	0.0031735
YEAR:FERT	1	0.00005991	0.00005991	0.1644	0.6887370
YEAR:HARV	1	0.00011377	0.00011377	0.3122	0.5815261
FERT:HARV	1	0.00001457	0.00001457	0.0400	0.8432069
YEAR:FERT:HARV	1	0.00001468	0.00001468	0.0403	0.8426121
Residuals	24	0.00874686	0.00036445		

1.5.1: KINLEITH SUMMER 2002

Kinleith FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00355874	0.003558738	1.759895	0.2012233
HARV	2	0.00648934	0.003244671	1.604580	0.2284237
FERT:HARV	2	0.00116645	0.000583223	0.288420	0.7528456
Residuals	18	0.03639835	0.002022131		

Kinleith FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.58066	0.580664	1.043691	0.3204997
HARV	2	5.68225	2.841124	5.106664	0.0175131
FERT:HARV	2	0.37382	0.186911	0.335956	0.7190406
Residuals	18	10.01441	0.556356		

Kinleith FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	346.498	346.498	0.667347	0.4246589
HARV	2	4865.004	2432.502	4.684942	0.0230142
FERT:HARV	2	995.809	497.905	0.958953	0.4020311
Residuals	18	9345.907	519.217		

Kinleith FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	34.0817	34.08167	1.992138	0.1751697
HARV	2	75.3890	37.69449	2.203314	0.1393362
FERT:HARV	2	3.5528	1.77640	0.103834	0.9019107
Residuals	18	307.9455	17.10809		

Kinleith FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.3775042	0.3775042	17.74519	0.0005235
HARV	2	0.2861083	0.1430542	6.72449	0.0065916
FERT:HARV	2	0.0875583	0.0437792	2.05791	0.1567203
Residuals	18	0.3829250	0.0212736		

Kinleith mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.062017	0.0620167	0.47641	0.4988568
HARV	2	1.243200	0.6216000	4.77511	0.0216934
FERT:HARV	2	0.022033	0.0110167	0.08463	0.9192159
Residuals	18	2.343150	0.1301750		

Kinleith mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000416667	0.0004166667	4.838710	0.0411326
HARV	2	0.000758333	0.0003791667	4.403226	0.0277523
FERT:HARV	2	0.000008333	0.0000041667	0.048387	0.9528884
Residuals	18	0.001550000	0.0000861111		

Kinleith FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	660.058	660.0577	11.63705	0.0031125
HARV	2	244.150	122.0751	2.15223	0.1451870
FERT:HARV	2	238.331	119.1655	2.10093	0.1513380
Residuals	18	1020.966	56.7204		

Kinleith Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00928160	0.00928160	4.131438	0.0571154
HARV	2	0.02633712	0.01316856	5.861607	0.0109545
FERT:HARV	2	0.00557787	0.00278893	1.241415	0.3125669
Residuals	18	0.04043841	0.00224658		

Kinleith Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0234375	0.0234375	0.457379	0.5074491
HARV	2	0.4332250	0.2166125	4.227158	0.0312596
FERT:HARV	2	0.0189250	0.0094625	0.184659	0.8329428
Residuals	18	0.9223750	0.0512431		

Kinleith Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.79854	1.79854	0.66425	0.4257152
HARV	2	94.54241	47.27120	17.45867	0.0000610
FERT:HARV	2	18.85102	9.42551	3.48112	0.0527108
Residuals	18	48.73692	2.70761		

Kinleith Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0504167	0.05041667	6.52408	0.01992281
HARV	2	0.1600083	0.08000417	10.35280	0.00101739
FERT:HARV	2	0.0506083	0.02530417	3.27444	0.06125852
Residuals	18	0.1391000	0.00772778		

Kinleith Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	40.64239	40.64239	24.93863	0.0000941
HARV	2	19.47502	9.73751	5.97504	0.0102299
FERT:HARV	2	1.62067	0.81033	0.49723	0.6163258
Residuals	18	29.33454	1.62970		

1.5.2: KINLEITH SUMMER 2003

```
Kinleith FH moisture content
          Df Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.0117333 0.01173326 1.903063 0.1846345
     HARV  2 0.0247185 0.01235926 2.004597 0.1636874
FERT:HARV  2 0.0143411 0.00717053 1.163017 0.3349490
Residuals 18 0.1109782 0.00616546
Kinleith FH oven dry ash free mass
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  2.947596 2.947596 7.485960 0.0135701
     HARV  2  2.259260 1.129630 2.868902 0.0828872
FERT:HARV  2  0.974442 0.487221 1.237386 0.3136756
Residuals 18  7.087499 0.393750
Kinleith FH density
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
     FERT  1      7.27    7.267 0.0018182 0.9664579
     HARV  2   4401.56 2200.780 0.5506425 0.5859888
FERT:HARV  2   5616.57 2808.287 0.7026428 0.5083609
Residuals 18  71941.49 3996.749
Kinleith FH carbon content (%)
          Df Sum of Sq  Mean Sq   F Value    Pr(F)
     FERT  1    3.2487 3.248704 0.4144819 0.527822
     HARV  2    0.5820 0.291004 0.0371274 0.963627
FERT:HARV  2    4.7759 2.387954 0.3046642 0.741099
Residuals 18  141.0838 7.837987
Kinleith FH nitrogen content (%)
          Df Sum of Sq    Mean Sq   F Value     Pr(F)
     FERT  1 0.0000167 0.00001667 0.0006166 0.9804629
     HARV  2 0.0139750 0.00698750 0.2585038 0.7750243
FERT:HARV  2 0.0455083 0.02275417 0.8417943 0.4472126
Residuals 18 0.4865500 0.02703056
Kinleith mass of carbon in FH litter
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.617604 0.6176042 5.809328 0.0268552
     HARV  2  0.489658 0.2448292 2.302920 0.1286669
FERT:HARV  2  0.300008 0.1500042 1.410974 0.2696251
Residuals 18  1.913625 0.1063125
Kinleith mass of nitrogen in FH litter
          Df    Sum of Sq      Mean Sq  F Value     Pr(F)
     FERT  1 0.0008166667 0.0008166667 16.33333 0.0007658
     HARV  2 0.0006333333 0.0003166667  6.33333 0.0082690
FERT:HARV  2 0.0000333333 0.0000166667  0.33333 0.7208611
Residuals 18 0.0009000000 0.0000500000
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Kinleith FH carbon: nitrogen ratio
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
     FERT  1    1.8320  1.83197 0.0651023 0.8014986
     HARV  2    8.4910  4.24552 0.1508721 0.8610339
FERT:HARV  2   54.0459 27.02296 0.9603092 0.4015385
Residuals 18  506.5174 28.13986
Kinleith Soil moisture content
          Df  Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.00608446 0.00608446 1.626635 0.2183845
     HARV  2 0.02625340 0.01312670 3.509324 0.0516509
FERT:HARV  2 0.01622945 0.00811472 2.169410 0.1431893
Residuals 18 0.06732938 0.00374052
```

1.5.3: KINLEITH SUMMER 2002 and 2003

Kinleith FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.6566127	0.6566127	160.3922	0.0000000
FERT	1	0.0141079	0.0141079	3.4462	0.0715981
HARV	2	0.0176960	0.0088480	2.1613	0.1298866
YEAR:FERT	1	0.0011841	0.0011841	0.2893	0.5940094
YEAR:HARV	2	0.0135119	0.0067559	1.6503	0.2061886
FERT:HARV	2	0.0092617	0.0046308	1.1312	0.3338506
YEAR:FERT:HARV	2	0.0062458	0.0031229	0.7628	0.4737283
Residuals	36	0.1473766	0.0040938		

Kinleith FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	3.73873	3.738731	7.870133	0.0080550
FERT	1	3.07240	3.072398	6.467483	0.0154272
HARV	2	6.12500	3.062501	6.446649	0.0040454
YEAR:FERT	1	0.45586	0.455863	0.959604	0.3338243
YEAR:HARV	2	1.81651	0.908254	1.911900	0.1625087
FERT:HARV	2	0.78589	0.392947	0.827165	0.4454270
YEAR:FERT:HARV	2	0.56237	0.281185	0.591902	0.5585682
Residuals	36	17.10191	0.475053		

Kinleith FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	156922.9	156922.9	69.49693	0.0000000
FERT	1	126.7	126.7	0.05611	0.8140905
HARV	2	3269.9	1634.9	0.72407	0.4916991
YEAR:FERT	1	227.1	227.1	0.10056	0.7529913
YEAR:HARV	2	5996.7	2998.3	1.32788	0.2777076
FERT:HARV	2	1060.4	530.2	0.23482	0.7919138
YEAR:FERT:HARV	2	5551.9	2776.0	1.22940	0.3044535
Residuals	36	81287.4	2258.0		

Kinleith FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1321.006	1321.006	105.9089	0.0000000
FERT	1	29.188	29.188	2.3401	0.1348255
HARV	2	35.146	17.573	1.4089	0.2575665
YEAR:FERT	1	8.143	8.143	0.6528	0.4244099
YEAR:HARV	2	40.825	20.412	1.6365	0.2088081
FERT:HARV	2	7.485	3.742	0.3000	0.7426319
YEAR:FERT:HARV	2	0.844	0.422	0.0338	0.9667559
Residuals	36	449.029	12.473		

Kinleith FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.7178521	0.7178521	29.72216	0.0000038
FERT	1	0.1912687	0.1912687	7.91935	0.0078779
HARV	2	0.1170542	0.0585271	2.42327	0.1029554
YEAR:FERT	1	0.1862521	0.1862521	7.71164	0.0086551
YEAR:HARV	2	0.1830292	0.0915146	3.78910	0.0321069
FERT:HARV	2	0.0336125	0.0168062	0.69585	0.5052320
YEAR:FERT:HARV	2	0.0994542	0.0497271	2.05891	0.1423545
Residuals	36	0.8694750	0.0241521		

Kinleith mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	2.046002	2.046002	17.30326	0.0001887
FERT	1	0.535519	0.535519	4.52894	0.0402419
HARV	2	1.379029	0.689515	5.83130	0.0064010
YEAR:FERT	1	0.144102	0.144102	1.21869	0.2769431
YEAR:HARV	2	0.353829	0.176915	1.49619	0.2375808
FERT:HARV	2	0.187363	0.093681	0.79227	0.4605510
YEAR:FERT:HARV	2	0.134679	0.067340	0.56950	0.5708239
Residuals	36	4.256775	0.118244		

Kinleith mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.001408333	0.001408333	20.69388	0.0000591
FERT	1	0.001200000	0.001200000	17.63265	0.0001679
HARV	2	0.001212500	0.000606250	8.90816	0.0007194
YEAR:FERT	1	0.000033333	0.000033333	0.48980	0.4885165
YEAR:HARV	2	0.000179167	0.000089583	1.31633	0.2807136
FERT:HARV	2	0.000012500	0.000006250	0.09184	0.9124671
YEAR:FERT:HARV	2	0.000029167	0.000014583	0.21429	0.8081398
Residuals	36	0.002450000	0.000068056		

Kinleith FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	10.472	10.4725	0.246817	0.6223455
FERT	1	365.718	365.7185	8.619316	0.0057639
HARV	2	108.719	54.3594	1.281152	0.2900759
YEAR:FERT	1	296.171	296.1712	6.980214	0.0121197
YEAR:HARV	2	143.922	71.9612	1.695995	0.1977436
FERT:HARV	2	142.521	71.2605	1.679480	0.2007521
YEAR:FERT:HARV	2	149.856	74.9280	1.765916	0.1855240
Residuals	36	1527.484	42.4301		

KINLEITH SUMMER 2002 and 2003 continued

Kinleith Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.2922518	0.2922518	97.62716	0.0000000
FERT	1	0.0151979	0.0151979	5.07689	0.0304344
HARV	2	0.0464019	0.0232009	7.75031	0.0015879
YEAR:FERT	1	0.0001681	0.0001681	0.05617	0.8140015
YEAR:HARV	2	0.0061887	0.0030943	1.03367	0.3660168
FERT:HARV	2	0.0162083	0.0081041	2.70720	0.0803010
YEAR:FERT:HARV	2	0.0055991	0.0027995	0.93519	0.4018394
Residuals	36	0.1077678	0.0029935		

1.6.1: GOLDEN DOWNS SUMMER 2002

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.01945327	0.01945327	7.87702	0.0116704
HARV	2	0.09480331	0.04740166	19.19387	0.0000344
FERT:HARV	2	0.00496442	0.00248221	1.00510	0.3856481
Residuals	18	0.04445324	0.00246962		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.19588	2.19588	1.20842	0.2861322
HARV	2	36.79804	18.39902	10.12516	0.0011317
FERT:HARV	2	3.33936	1.66968	0.91884	0.4169015
Residuals	18	32.70884	1.81716		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.08	0.081	0.000115	0.9915506
HARV	2	8622.95	4311.477	6.137187	0.0092849
FERT:HARV	2	455.50	227.750	0.324191	0.7272473
Residuals	18	12645.30	702.517		

Golden Downs FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.8222	2.82220	0.154795	0.6986161
HARV	2	161.2761	80.63803	4.422906	0.0273882
FERT:HARV	2	36.0400	18.02000	0.988377	0.3914968
Residuals	18	328.1744	18.23191		

Golden Downs FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.3266667	0.3266667	18.66370	0.0004123
HARV	2	0.4104250	0.2052125	11.72457	0.0005493
FERT:HARV	2	0.0829083	0.0414542	2.36843	0.1221453
Residuals	18	0.3150500	0.0175028		

Golden Downs mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.59850	0.598504	1.14876	0.2979702
HARV	2	10.63276	5.316379	10.20416	0.0010905
FERT:HARV	2	0.76591	0.382954	0.73503	0.4933385
Residuals	18	9.37803	0.521001		

Golden Downs mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000416667	0.000416667	2.631579	0.1221416
HARV	2	0.003100000	0.001550000	9.789474	0.0013272
FERT:HARV	2	0.000833333	0.000416667	2.631579	0.0994110
Residuals	18	0.002850000	0.000158333		

Golden Downs FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	760.140	760.1401	12.46014	0.0023925
HARV	2	1478.569	739.2844	12.11828	0.0004637
FERT:HARV	2	246.366	123.1830	2.01920	0.1617449
Residuals	18	1098.103	61.0057		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00194945	0.001949447	0.5879811	0.4531414
HARV	2	0.00661174	0.003305871	0.9970981	0.3884338
FERT:HARV	2	0.00153210	0.000766050	0.2310515	0.7960164
Residuals	18	0.05967886	0.003315492		

Golden Downs Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0160167	0.01601667	0.427206	0.5216260
HARV	2	0.0897750	0.04488750	1.197266	0.3249592
FERT:HARV	2	0.0723583	0.03617917	0.964992	0.3998434
Residuals	18	0.6748500	0.03749167		

Golden Downs Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.7604	1.76042	0.058823	0.8111084
HARV	2	187.6996	93.84980	3.135907	0.0678473
FERT:HARV	2	5.7851	2.89253	0.096651	0.9083405
Residuals	18	538.6946	29.92748		

Golden Downs Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0150000	0.01500000	0.608245	0.4455840
HARV	2	0.1236083	0.06180417	2.506139	0.1096014
FERT:HARV	2	0.0032250	0.00161250	0.065386	0.9369269
Residuals	18	0.4439000	0.02466111		

Golden Downs Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	65.1630	65.16296	10.83093	0.0040608
HARV	2	87.1779	43.58894	7.24505	0.0049169
FERT:HARV	2	2.0856	1.04278	0.17332	0.8422529
Residuals	18	108.2948	6.01638		

1.6.2: GOLDEN DOWNS SUMMER 2003

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00002943	0.000029434	0.027034	0.8712320
HARV	2	0.00942238	0.004711189	4.327042	0.0292132
FERT:HARV	2	0.00352824	0.001764122	1.620277	0.2254031
Residuals	18	0.01959801	0.001088778		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.06347	1.063470	1.061425	0.3165360
HARV	2	15.60313	7.801565	7.786568	0.0036604
FERT:HARV	2	0.12425	0.062125	0.062006	0.9400772
Residuals	18	18.03467	1.001926		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	268.79	268.790	0.205322	0.6558732
HARV	2	7938.76	3969.379	3.032117	0.0733000
FERT:HARV	2	866.74	433.371	0.331042	0.7224558
Residuals	18	23564.01	1309.112		

Golden Downs FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.0417	1.04167	0.171420	0.6837443
HARV	2	12.3959	6.19795	1.019957	0.3805308
FERT:HARV	2	43.7744	21.88718	3.601831	0.0483370
Residuals	18	109.3802	6.07668		

Golden Downs FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.053204	0.05320417	0.9425239	0.3444955
HARV	2	0.030008	0.01500417	0.2658022	0.7695474
FERT:HARV	2	0.110008	0.05500417	0.9744113	0.3964579
Residuals	18	1.016075	0.05644861		

Golden Downs mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.283837	0.283837	1.154156	0.2968719
HARV	2	3.815108	1.907554	7.756606	0.0037197
FERT:HARV	2	0.017775	0.008888	0.036139	0.9645761
Residuals	18	4.426675	0.245926		

Golden Downs mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000104167	0.000104167	0.454545	0.5087509
HARV	2	0.002033333	0.001016667	4.436364	0.0271423
FERT:HARV	2	0.000033333	0.000016667	0.072727	0.9301262
Residuals	18	0.004125000	0.000229167		

Golden Downs FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	201.160	201.1601	1.485861	0.2385941
HARV	2	25.711	12.8556	0.094957	0.9098642
FERT:HARV	2	54.839	27.4195	0.202533	0.8184948
Residuals	18	2436.891	135.3828		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000471103	0.000471103	1.33282	0.2634027
HARV	2	0.009384187	0.004692094	13.27458	0.0002870
FERT:HARV	2	0.000256542	0.000128271	0.36290	0.7006333
Residuals	18	0.006362364	0.000353465		

1.6.3: GOLDEN DOWNS WINTER 2002

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00190588	0.001905875	1.685764	0.2105499
HARV	2	0.00106239	0.000531197	0.469849	0.6325505
FERT:HARV	2	0.00164083	0.000820417	0.725666	0.4976319
Residuals	18	0.02035028	0.001130571		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00512	0.005117	0.008147	0.9290788
HARV	2	8.25780	4.128901	6.572840	0.0071924
FERT:HARV	2	0.38260	0.191298	0.304529	0.7411962
Residuals	18	11.30717	0.628176		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4.297	4.297	0.028215	0.8684776
HARV	2	2786.481	1393.241	9.147505	0.0018148
FERT:HARV	2	65.243	32.622	0.214181	0.8092295
Residuals	18	2741.549	152.308		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0032722	0.00327219	0.358985	0.5565371
HARV	2	0.0745925	0.03729627	4.091690	0.0342942
FERT:HARV	2	0.0233763	0.01168814	1.282280	0.3015628
Residuals	18	0.1640722	0.00911512		

1.6.4: GOLDEN DOWNS WINTER 2003

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.00001975	0.0000197454	0.0299255	0.8645897
HARV	2	0.00046082	0.0002304119	0.3492058	0.7099211
FERT:HARV	2	0.00104704	0.0005235192	0.7934310	0.4674862
Residuals	18	0.01187670	0.0006598169		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.125837	1.125837	2.750665	0.1145376
HARV	2	7.028127	3.514063	8.585624	0.0024086
FERT:HARV	2	2.051411	1.025705	2.506022	0.1096114
Residuals	18	7.367332	0.409296		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	3188.26	3188.259	4.472673	0.0486504
HARV	2	2239.87	1119.933	1.571107	0.2350165
FERT:HARV	2	8237.43	4118.717	5.777974	0.0115252
Residuals	18	12830.95	712.831		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0119620	0.01196195	1.843087	0.1913674
HARV	2	0.1146907	0.05734533	8.835720	0.0021211
FERT:HARV	2	0.0222975	0.01114873	1.717787	0.2076044
Residuals	18	0.1168231	0.00649017		

1.6.5: GOLDEN DOWNS SUMMER 2002 and 2003

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1.050909	1.050909	590.6633	0.0000000
FERT	1	0.010498	0.010498	5.9004	0.0202573
HARV	2	0.079959	0.039979	22.4705	0.0000005
YEAR:FERT	1	0.008985	0.008985	5.0498	0.0308520
YEAR:HARV	2	0.024267	0.012133	6.8196	0.0030805
FERT:HARV	2	0.008260	0.004130	2.3213	0.1126617
YEAR:FERT:HARV	2	0.000233	0.000116	0.0653	0.9368544
Residuals	36	0.064051	0.001779		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	2.11025	2.11025	1.49712	0.2290638
FERT	1	3.15783	3.15783	2.24032	0.1431697
HARV	2	50.14896	25.07448	17.78910	0.0000042
YEAR:FERT	1	0.10152	0.10152	0.07202	0.7899431
YEAR:HARV	2	2.25221	1.12610	0.79892	0.4576303
FERT:HARV	2	1.57393	0.78696	0.55831	0.5770491
YEAR:FERT:HARV	2	1.88969	0.94484	0.67032	0.5178135
Residuals	36	50.74350	1.40954		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	60879.97	60879.97	60.52805	0.0000000
FERT	1	129.77	129.77	0.12902	0.7215494
HARV	2	15004.77	7502.39	7.45902	0.0019487
YEAR:FERT	1	139.10	139.10	0.13830	0.7121594
YEAR:HARV	2	1556.94	778.47	0.77397	0.4687004
FERT:HARV	2	1030.27	515.13	0.51216	0.6035028
YEAR:FERT:HARV	2	291.97	145.99	0.14514	0.8654019
Residuals	36	36209.31	1005.81		

Golden Downs FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	4.6688	4.66877	0.384125	0.5393072
FERT	1	0.2174	0.21735	0.017883	0.8943637
HARV	2	48.9845	24.49223	2.015109	0.1480683
YEAR:FERT	1	3.6465	3.64652	0.300019	0.5872509
YEAR:HARV	2	124.6875	62.34376	5.129359	0.0109638
FERT:HARV	2	2.4723	1.23616	0.101706	0.9035537
YEAR:FERT:HARV	2	77.3420	38.67102	3.181675	0.0534097
Residuals	36	437.5547	12.15430		

Golden Downs FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.068252	0.0682521	1.845863	0.1827179
FERT	1	0.058102	0.0581021	1.571359	0.2180898
HARV	2	0.331179	0.1655896	4.478336	0.0183295
YEAR:FERT	1	0.321769	0.3217687	8.702169	0.0055572
YEAR:HARV	2	0.109254	0.0546271	1.477378	0.2417443
FERT:HARV	2	0.012454	0.0062271	0.168410	0.8456690
YEAR:FERT:HARV	2	0.180462	0.0902312	2.440285	0.1014238
Residuals	36	1.331125	0.0369757		

Golden Downs mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.71053	0.710533	1.85293	0.1819026
FERT	1	0.85333	0.853333	2.22533	0.1444756
HARV	2	13.58685	6.793425	17.71594	0.0000044
YEAR:FERT	1	0.02901	0.029008	0.07565	0.7848563
YEAR:HARV	2	0.86102	0.430508	1.12268	0.3365319
FERT:HARV	2	0.44847	0.224233	0.58476	0.5624462
YEAR:FERT:HARV	2	0.33522	0.167608	0.43709	0.6492952
Residuals	36	13.80470	0.383464		

Golden Downs mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.000002083	0.000002083	0.01075	0.9179868
FERT	1	0.000468750	0.000468750	2.41935	0.1285927
HARV	2	0.005016667	0.002508333	12.94624	0.0000581
YEAR:FERT	1	0.000052083	0.000052083	0.26882	0.6072987
YEAR:HARV	2	0.000116667	0.000058333	0.30108	0.7418672
FERT:HARV	2	0.000350000	0.000175000	0.90323	0.4142462
YEAR:FERT:HARV	2	0.000516667	0.000258333	1.33333	0.2763018
Residuals	36	0.006975000	0.000193750		

Golden Downs FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	105.774	105.7735	1.077186	0.3062490
FERT	1	89.613	89.6132	0.912611	0.3457939
HARV	2	945.618	472.8089	4.815034	0.0140257
YEAR:FERT	1	871.687	871.6870	8.877166	0.0051461
YEAR:HARV	2	558.662	279.3311	2.844678	0.0712839
FERT:HARV	2	82.282	41.1408	0.418974	0.6608873
YEAR:FERT:HARV	2	218.923	109.4617	1.114747	0.3390559
Residuals	36	3534.994	98.1943		

GOLDEN DOWNS SUMMER 2002 and 2003 continued

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.1887847	0.1887847	102.9092	0.0000000
FERT	1	0.0002519	0.0002519	0.1373	0.7131112
HARV	2	0.0149138	0.0074569	4.0649	0.0256028
YEAR:FERT	1	0.0021686	0.0021686	1.1821	0.2841479
YEAR:HARV	2	0.0010822	0.0005411	0.2950	0.7463493
FERT:HARV	2	0.0011613	0.0005806	0.3165	0.7306950
YEAR:FERT:HARV	2	0.0006274	0.0003137	0.1710	0.8435046
Residuals	36	0.0660412	0.0018345		

1.6.6: GOLDEN DOWNS WINTER 2002 and 2003

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.00239712	0.002397125	2.677771	0.1104722
FERT	1	0.00076882	0.000768820	0.858831	0.3602377
HARV	2	0.00083714	0.000418572	0.467577	0.6302700
YEAR:FERT	1	0.00115680	0.001156801	1.292235	0.2631469
YEAR:HARV	2	0.00068607	0.000343037	0.383199	0.6844245
FERT:HARV	2	0.00095145	0.000475727	0.531423	0.5923075
YEAR:FERT:HARV	2	0.00173642	0.000868210	0.969857	0.3888232
Residuals	36	0.03222698	0.000895194		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	4.60393	4.603926	8.87527	0.0051504
FERT	1	0.64138	0.641381	1.23643	0.2735309
HARV	2	15.19201	7.596006	14.64329	0.0000222
YEAR:FERT	1	0.48957	0.489573	0.94378	0.3377900
YEAR:HARV	2	0.09392	0.046959	0.09053	0.9136578
FERT:HARV	2	2.07370	1.036850	1.99880	0.1502567
YEAR:FERT:HARV	2	0.36031	0.180153	0.34729	0.7089407
Residuals	36	18.67450	0.518736		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	170059.4	170059.4	393.1379	0.0000000
FERT	1	1479.2	1479.2	3.4196	0.0726501
HARV	2	4993.2	2496.6	5.7715	0.0066971
YEAR:FERT	1	1713.3	1713.3	3.9608	0.0542065
YEAR:HARV	2	33.2	16.6	0.0384	0.9623948
FERT:HARV	2	4560.6	2280.3	5.2715	0.0098191
YEAR:FERT:HARV	2	3742.1	1871.1	4.3254	0.0207254
Residuals	36	15572.5	432.6		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.0237074	0.02370743	3.03838	0.0898535
FERT	1	0.0138734	0.01387341	1.77804	0.1907667
HARV	2	0.1864248	0.09321239	11.94625	0.0001049
YEAR:FERT	1	0.0013607	0.00136073	0.17439	0.6787167
YEAR:HARV	2	0.0028584	0.00142921	0.18317	0.8333975
FERT:HARV	2	0.0456223	0.02281115	2.92351	0.0666012
YEAR:FERT:HARV	2	0.0000515	0.00002573	0.00330	0.9967087
Residuals	36	0.2808953	0.00780265		

1.6.7: GOLDEN DOWNS SUMMER and WINTER (2002 and 2003)

Golden Downs FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.576844	0.576844	431.383	0.0000000
SEASON	1	3.867778	3.867778	2892.451	0.0000000
FERT	1	0.008474	0.008474	6.337	0.0140476
HARV	2	0.033431	0.016715	12.500	0.0000219
YEAR:SEASON	1	0.476462	0.476462	356.314	0.0000000
YEAR:FERT	1	0.008295	0.008295	6.203	0.0150611
SEASON:FERT	1	0.002792	0.002792	2.088	0.1527698
YEAR:HARV	2	0.012047	0.006024	4.505	0.0143456
SEASON:HARV	2	0.047365	0.023683	17.711	0.0000006
FERT:HARV	2	0.007357	0.003679	2.751	0.0705785
YEAR:SEASON:FERT	1	0.001847	0.001847	1.381	0.2437811
YEAR:SEASON:HARV	2	0.012906	0.006453	4.826	0.0107972
YEAR:FERT:HARV	2	0.000455	0.000227	0.170	0.8439421
SEASON:FERT:HARV	2	0.001854	0.000927	0.693	0.5032382
YEAR:SEASON:FERT:HARV	2	0.001514	0.000757	0.566	0.5702139
Residuals	72	0.096278	0.001337		

Golden Downs FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.24013	0.24013	0.24906	0.6192590
SEASON	1	7.12505	7.12505	7.39007	0.0082121
FERT	1	3.32276	3.32276	3.44635	0.0674831
HARV	2	60.00109	30.00055	31.11641	0.0000000
YEAR:SEASON	1	6.47405	6.47405	6.71485	0.0115685
YEAR:FERT	1	0.07261	0.07261	0.07531	0.7845458
SEASON:FERT	1	0.47645	0.47645	0.49417	0.4843396
YEAR:HARV	2	1.38369	0.69185	0.71758	0.4913875
SEASON:HARV	2	5.33988	2.66994	2.76925	0.0693976
FERT:HARV	2	1.11592	0.55796	0.57872	0.5632043
YEAR:SEASON:FERT	1	0.51849	0.51849	0.53777	0.4657382
YEAR:SEASON:HARV	2	0.96243	0.48122	0.49912	0.6091523
YEAR:FERT:HARV	2	1.83547	0.91774	0.95187	0.3908215
SEASON:FERT:HARV	2	2.53170	1.26585	1.31294	0.2753919
YEAR:SEASON:FERT:HARV	2	0.41452	0.20726	0.21497	0.8070817
Residuals	72	69.41801	0.96414		

Golden Downs FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	217220.4	217220.4	302.0341	0.0000000
SEASON	1	4973.1	4973.1	6.9149	0.0104454
FERT	1	1242.6	1242.6	1.7278	0.1928625
HARV	2	18624.6	9312.3	12.9483	0.0000157
YEAR:SEASON	1	13719.0	13719.0	19.0755	0.0000414
YEAR:FERT	1	1414.4	1414.4	1.9667	0.1651002
SEASON:FERT	1	366.4	366.4	0.5094	0.4776993
YEAR:HARV	2	961.6	480.8	0.6686	0.5155992
SEASON:HARV	2	1373.3	686.7	0.9548	0.3897157
FERT:HARV	2	4795.5	2397.7	3.3339	0.0412354
YEAR:SEASON:FERT	1	438.0	438.0	0.6091	0.4377017
YEAR:SEASON:HARV	2	628.5	314.2	0.4369	0.6477094
YEAR:FERT:HARV	2	1851.2	925.6	1.2870	0.2823638
SEASON:FERT:HARV	2	795.4	397.7	0.5530	0.5776626
YEAR:SEASON:FERT:HARV	2	2182.8	1091.4	1.5176	0.2261743
Residuals	72	51781.8	719.2		

Golden Downs Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	0.1731460	0.1731460	35.9331	0.0000001
SEASON	1	0.8730578	0.8730578	181.1863	0.0000000
FERT	1	0.0089323	0.0089323	1.8537	0.1775967
HARV	2	0.1533972	0.0766986	15.9173	0.0000019
YEAR:SEASON	1	0.0393461	0.0393461	8.1655	0.0055783
YEAR:FERT	1	0.0000469	0.0000469	0.0097	0.9217240
SEASON:FERT	1	0.0051931	0.0051931	1.0777	0.3026809
YEAR:HARV	2	0.0033105	0.0016552	0.3435	0.7104315
SEASON:HARV	2	0.0479413	0.0239707	4.9746	0.0094698
FERT:HARV	2	0.0240719	0.0120360	2.4978	0.0893685
YEAR:SEASON:FERT	1	0.0034825	0.0034825	0.7227	0.3980708
YEAR:SEASON:HARV	2	0.0006301	0.0003151	0.0654	0.9367616
YEAR:FERT:HARV	2	0.0001664	0.0000832	0.0173	0.9828823
SEASON:FERT:HARV	2	0.0227116	0.0113558	2.3567	0.1020030
YEAR:SEASON:FERT:HARV	2	0.0005124	0.0002562	0.0532	0.9482567
Residuals	72	0.3469366	0.0048186		

1.7.1: FERTILISATION AT ALL SITES SUMMER 2002

All Sites FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.281377	0.2562754	91.45080	0.00000000
FERT	1	0.046386	0.0463857	16.55252	0.00008930
SITE:FERT	5	0.029488	0.0058977	2.10457	0.07016658
Residuals	110	0.308256	0.0028023		

All Sites FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	578.8013	115.7603	45.57592	0.0000000
FERT	1	25.9277	25.9277	10.20799	0.0018249
SITE:FERT	5	7.9700	1.5940	0.62758	0.6790547
Residuals	110	279.3937	2.5399		

All Sites FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	171555.5	34311.10	38.51644	0.00000000
FERT	1	3159.3	3159.33	3.54656	0.06231040
SITE:FERT	5	24183.3	4836.66	5.42946	0.00016744
Residuals	110	97989.9	890.82		

All Sites FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	5414.561	1082.912	43.88439	0.000000000
FERT	1	203.943	203.943	8.26467	0.004854137
SITE:FERT	5	962.396	192.479	7.80011	0.000002582
Residuals	110	2714.412	24.676		

All Sites FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.205078	0.241016	7.9436	0.000002020
FERT	1	3.974430	3.974430	130.9927	0.000000000
SITE:FERT	5	0.626353	0.125271	4.1288	0.001785068
Residuals	110	3.337493	0.030341		

All Sites mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	42.81015	8.562031	16.79526	0.00000000
FERT	1	8.48264	8.482642	16.63953	0.00008582
SITE:FERT	5	7.70598	1.541196	3.02321	0.01351159
Residuals	110	56.07675	0.509789		

All Sites mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.05066615	0.01013323	29.33123	0.000000e+000
FERT	1	0.01677200	0.01677200	48.54754	2.490000e-010
SITE:FERT	5	0.01319205	0.00263841	7.63703	3.416307e-006
Residuals	110	0.03800234	0.00034548		

All Sites FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	6904.825	1380.965	27.03404	0.00000000
FERT	1	2807.579	2807.579	54.96172	0.00000000
SITE:FERT	5	557.607	111.521	2.18316	0.06112479
Residuals	110	5619.069	51.082		

All Sites Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.858592	0.3717183	181.9901	0.0000000
FERT	1	0.000231	0.0002314	0.1133	0.7370509
SITE:FERT	5	0.014293	0.0028586	1.3995	0.2300518
Residuals	110	0.224677	0.0020425		

All Sites Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	12.77244	2.554487	39.62999	0.0000000000
FERT	1	1.44121	1.441210	22.35875	0.0000067492
SITE:FERT	5	1.49732	0.299465	4.64586	0.0006936166
Residuals	110	7.09043	0.064458		

All Sites Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2116.926	423.3852	43.98461	0.0000000
FERT	1	7.650	7.6497	0.79471	0.3746257
SITE:FERT	5	14.236	2.8473	0.29580	0.9143307
Residuals	110	1058.833	9.6258		

All Sites Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3.459433	0.6918866	58.64380	0.0000000
FERT	1	0.147447	0.1474467	12.49747	0.0005975
SITE:FERT	5	0.026265	0.0052529	0.44523	0.8159399
Residuals	110	1.297793	0.0117981		

All Sites Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3292.188	658.4376	54.46120	0.000000000
FERT	1	424.820	424.8203	35.13806	0.000000036
SITE:FERT	5	212.074	42.4147	3.50824	0.005567545
Residuals	110	1329.903	12.0900		

1.7.2: FERTILISATION AT ALL SITES SUMMER 2003

```
All Sites FH moisture content
           Df Sum of Sq   Mean Sq  F Value      Pr(F)
     SITE   5  4.362213 0.8724426 267.3499 0.00000000
     FERT   1  0.009996 0.0099961   3.0632 0.08287221
SITE:FERT   5  0.036147 0.0072293   2.2153 0.05775553
Residuals 110  0.358963 0.0032633
All Sites FH oven dry ash free mass
           Df Sum of Sq  Mean Sq  F Value       Pr(F)
     SITE   5   60.6311 12.12622 10.95839 0.000000014
     FERT   1   54.1618 54.16183 48.94573 0.000000000
SITE:FERT   5   19.4176  3.88352  3.50952 0.005554557
Residuals 110  121.7226  1.10657
All Sites FH density
           Df Sum of Sq  Mean Sq  F Value     Pr(F)
     SITE   5  256461.9 51292.37 32.52382 0.0000000
     FERT   1    2031.4  2031.39  1.28808 0.2588695
SITE:FERT   5    3338.2   667.63  0.42334 0.8315968
Residuals 110  173477.8  1577.07
All Sites FH carbon content (%)
           Df Sum of Sq  Mean Sq  F Value     Pr(F)
     SITE   5   575.769 115.1538 9.585513 0.0000001
     FERT   1    10.408  10.4080 0.866375 0.3539991
SITE:FERT   5    43.066   8.6132 0.716974 0.6120077
Residuals 110  1321.464  12.0133
All Sites FH nitrogen content (%)
           Df Sum of Sq   Mean Sq  F Value      Pr(F)
     SITE   5  2.267892 0.4535783 12.39326 0.00000000
     FERT   1  0.214205 0.2142046  5.85278 0.01719230
SITE:FERT   5  0.933596 0.1867191  5.10178 0.00030276
Residuals 110  4.025868 0.0365988
All Sites mass of carbon in FH litter
           Df Sum of Sq  Mean Sq  F Value       Pr(F)
     SITE   5  13.94195  2.78839 11.34386 0.000000008
     FERT   1  11.97341 11.97341 48.71079 0.000000000
SITE:FERT   5   4.41247  0.88249  3.59020 0.004791038
Residuals 110  27.03867  0.24581
All Sites mass of nitrogen in FH litter
           Df  Sum of Sq     Mean Sq  F Value        Pr(F)
     SITE   5 0.00726499 0.001452998  8.23259 0.0000012357
     FERT   1 0.00977687 0.009776870 55.39510 0.0000000000
SITE:FERT   5 0.00480324 0.000960649  5.44297 0.0001634091
Residuals 110 0.01941428 0.000176493
```

```
All Sites FH carbon: nitrogen ratio
           Df Sum of Sq  Mean Sq  F Value     Pr(F)
     SITE   5  3361.515 672.3029 7.642104 0.0000034
     FERT   1    58.543  58.5428 0.665460 0.4164020
SITE:FERT   5  1355.435 271.0870 3.081460 0.0121506
Residuals 110  9677.089  87.9735
All Sites Soil moisture content
           Df Sum of Sq   Mean Sq  F Value     Pr(F)
     SITE   5  1.247419 0.2494839 78.43900 0.0000000
     FERT   1  0.004611 0.0046108  1.44966 0.2311667
SITE:FERT   5  0.003757 0.0007515  0.23626 0.9457447
Residuals 110  0.349867 0.0031806
```

1.7.3: FERTILISATION AT ALL SITES SUMMER 2002 and 2003

All Sites FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3.778608	0.755722	249.1816	0.0000000
YEAR	1	2.849829	2.849829	939.6646	0.0000000
FERT	1	0.049724	0.049724	16.3953	0.0000712
SITE:YEAR	5	1.864982	0.372996	122.9869	0.0000000
SITE:FERT	5	0.040821	0.008164	2.6919	0.0219920
YEAR:FERT	1	0.006658	0.006658	2.1952	0.1398693
SITE:YEAR:FERT	5	0.024814	0.004963	1.6364	0.1514540
Residuals	220	0.667219	0.003033		

All Sites FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	387.0301	77.40601	42.45482	0.0000000
YEAR	1	63.1765	63.17650	34.65037	0.0000000
FERT	1	77.5187	77.51866	42.51661	0.0000000
SITE:YEAR	5	252.4023	50.48046	27.68698	0.0000000
SITE:FERT	5	24.1123	4.82245	2.64497	0.0240485
YEAR:FERT	1	2.5709	2.57088	1.41005	0.2363287
SITE:YEAR:FERT	5	3.2754	0.65507	0.35929	0.8758982
Residuals	220	401.1163	1.82326		

All Sites FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	227530.8	45506.15	36.87862	0.0000000
YEAR	1	77409.3	77409.34	62.73327	0.0000000
FERT	1	62.0	62.02	0.05026	0.8228217
SITE:YEAR	5	200486.6	40097.32	32.49526	0.0000000
SITE:FERT	5	18431.0	3686.20	2.98733	0.0124727
YEAR:FERT	1	5128.7	5128.71	4.15635	0.0426746
SITE:YEAR:FERT	5	9090.4	1818.09	1.47340	0.1995775
Residuals	220	271467.7	1233.94		

All Sites FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	4162.604	832.521	45.3816	0.00000000
YEAR	1	3703.941	3703.941	201.9058	0.00000000
FERT	1	153.248	153.248	8.3537	0.00423444
SITE:YEAR	5	1827.726	365.545	19.9263	0.00000000
SITE:FERT	5	569.587	113.917	6.2098	0.00002081
YEAR:FERT	1	61.103	61.103	3.3308	0.06934958
SITE:YEAR:FERT	5	435.875	87.175	4.7520	0.00038272
Residuals	220	4035.877	18.345		

All Sites FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.046446	0.409289	12.22861	0.0000000
YEAR	1	0.621448	0.621448	18.56742	0.0000247
FERT	1	3.016999	3.016999	90.14086	0.0000000
SITE:YEAR	5	1.426524	0.285305	8.52424	0.0000002
SITE:FERT	5	1.348246	0.269649	8.05649	0.0000005
YEAR:FERT	1	1.171636	1.171636	35.00573	0.0000000
SITE:YEAR:FERT	5	0.211703	0.042341	1.26504	0.2800764
Residuals	220	7.363361	0.033470		

All Sites mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	39.46823	7.89365	20.89386	0.0000000
YEAR	1	2.03632	2.03632	5.38998	0.0211675
FERT	1	20.30603	20.30603	53.74846	0.0000000
SITE:YEAR	5	17.28387	3.45677	9.14981	0.0000001
SITE:FERT	5	10.58780	2.11756	5.60501	0.0000696
YEAR:FERT	1	0.15002	0.15002	0.39710	0.5292458
SITE:YEAR:FERT	5	1.53065	0.30613	0.81030	0.5433966
Residuals	220	83.11542	0.37780		

All Sites mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.03943269	0.00788654	30.21840	0.0000000
YEAR	1	0.00397859	0.00397859	15.24453	0.0001256
FERT	1	0.02607981	0.02607981	99.92855	0.0000000
SITE:YEAR	5	0.01849844	0.00369969	14.17589	0.0000000
SITE:FERT	5	0.01679116	0.00335823	12.86755	0.0000000
YEAR:FERT	1	0.00046906	0.00046906	1.79727	0.1814260
SITE:YEAR:FERT	5	0.00120413	0.00024083	0.92276	0.4669985
Residuals	220	0.05741662	0.00026098		

All Sites FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	9093.76	1818.751	26.15855	0.0000000
YEAR	1	893.00	892.996	12.84369	0.0004170
FERT	1	1838.48	1838.479	26.44228	0.0000006
SITE:YEAR	5	1172.58	234.516	3.37298	0.0058891
SITE:FERT	5	328.25	65.651	0.94423	0.4531994
YEAR:FERT	1	1027.64	1027.643	14.78028	0.0001581
SITE:YEAR:FERT	5	1584.79	316.958	4.55871	0.0005629
Residuals	220	15296.16	69.528		

FERTILISATION AT ALL SITES SUMMER 2002 and 2003 continued

All Sites Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.299330	0.4598660	176.0883	0.0000000
YEAR	1	0.558940	0.5589396	214.0248	0.0000000
FERT	1	0.001388	0.0013881	0.5315	0.4667407
SITE:YEAR	5	0.806681	0.1613362	61.7776	0.0000000
SITE:FERT	5	0.014347	0.0028693	1.0987	0.3620370
YEAR:FERT	1	0.003454	0.0034541	1.3226	0.2513700
SITE:YEAR:FERT	5	0.003704	0.0007407	0.2836	0.9217586
Residuals	220	0.574544	0.0026116		

1.8.1: WT and SO HARVESTING AT ALL SITES SUMMER 2002

WT and SO plots FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.7439144	0.1487829	106.3535	0.0000000
FERT	1	0.0236619	0.0236619	16.9141	0.0001077
HARV	1	0.0002003	0.0002003	0.1432	0.7063124
SITE:FERT	5	0.0222677	0.0044535	3.1835	0.0121679
SITE:HARV	5	0.0181493	0.0036299	2.5947	0.0330526
FERT:HARV	1	0.0015933	0.0015933	1.1389	0.2896546
SITE:FERT:HARV	5	0.0153071	0.0030614	2.1884	0.0655285
Residuals	68	0.0951284	0.0013989		

WT and SO plots FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	537.7457	107.5491	68.91109	0.0000000
FERT	1	16.5137	16.5137	10.58099	0.0017805
HARV	1	38.4622	38.4622	24.64429	0.0000049
SITE:FERT	5	2.8019	0.5604	0.35906	0.8746708
SITE:HARV	5	6.5438	1.3088	0.83857	0.5270084
FERT:HARV	1	1.7926	1.7926	1.14857	0.2876380
SITE:FERT:HARV	5	2.1469	0.4294	0.27512	0.9252291
Residuals	68	106.1272	1.5607		

WT and SO plots FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	98817.61	19763.52	32.70048	0.0000000
FERT	1	2334.30	2334.30	3.86231	0.0534687
HARV	1	3098.05	3098.05	5.12600	0.0267636
SITE:FERT	5	18146.45	3629.29	6.00498	0.0001168
SITE:HARV	5	4100.39	820.08	1.35689	0.2515226
FERT:HARV	1	223.20	223.20	0.36931	0.5454069
SITE:FERT:HARV	5	2926.04	585.21	0.96828	0.4435029
Residuals	68	41097.86	604.38		

WT and SO plots FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3806.971	761.3942	50.77457	0.0000000
FERT	1	86.720	86.7201	5.78304	0.0189096
HARV	1	178.744	178.7438	11.91977	0.0009597
SITE:FERT	5	668.190	133.6380	8.91182	0.0000015
SITE:HARV	5	51.476	10.2953	0.68655	0.6352388
FERT:HARV	1	2.209	2.2088	0.14730	0.7023301
SITE:FERT:HARV	5	97.440	19.4880	1.29958	0.2744711
Residuals	68	1019.699	14.9956		

WT and SO plots FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.547005	0.309401	18.0074	0.0000000
FERT	1	2.541132	2.541132	147.8962	0.0000000
HARV	1	0.025445	0.025445	1.4809	0.2278410
SITE:FERT	5	0.596102	0.119220	6.9387	0.0000275
SITE:HARV	5	0.154814	0.030963	1.8021	0.1241126
FERT:HARV	1	0.019810	0.019810	1.1529	0.2867286
SITE:FERT:HARV	5	0.091374	0.018275	1.0636	0.3882735
Residuals	68	1.168367	0.017182		

WT and SO plots mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	45.24306	9.048611	27.73667	0.0000000
FERT	1	6.68035	6.680350	20.47725	0.0000249
HARV	1	9.33089	9.330887	28.60193	0.0000011
SITE:FERT	5	5.63492	1.126984	3.45454	0.0076848
SITE:HARV	5	1.88690	0.377381	1.15678	0.3394915
FERT:HARV	1	0.51620	0.516200	1.58231	0.2127315
SITE:FERT:HARV	5	0.41532	0.083064	0.25462	0.9360743
Residuals	68	22.18383	0.326233		

WT and SO plots mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.04984667	0.00996933	45.71797	0.0000000
FERT	1	0.01360437	0.01360437	62.38774	0.0000000
HARV	1	0.00578900	0.00578900	26.54755	0.0000024
SITE:FERT	5	0.00990760	0.00198152	9.08698	0.0000012
SITE:HARV	5	0.00159606	0.00031921	1.46386	0.2131421
FERT:HARV	1	0.00007718	0.00007718	0.35394	0.5538677
SITE:FERT:HARV	5	0.00052831	0.00010566	0.48455	0.7866225
Residuals	68	0.01482819	0.00021806		

WT and SO plots FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	7952.892	1590.578	48.87300	0.0000000
FERT	1	1995.339	1995.339	61.30988	0.0000000
HARV	1	51.278	51.278	1.57559	0.2136940
SITE:FERT	5	500.761	100.152	3.07733	0.0145715
SITE:HARV	5	106.118	21.224	0.65213	0.6608498
FERT:HARV	1	18.472	18.472	0.56757	0.4538256
SITE:FERT:HARV	5	249.554	49.911	1.53358	0.1910290
Residuals	68	2213.070	32.545		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 continued

WT and SO plots Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.418363	0.2836726	144.2404	0.0000000
FERT	1	0.000010	0.0000102	0.0052	0.9427346
HARV	1	0.001217	0.0012173	0.6190	0.4341563
SITE:FERT	5	0.011226	0.0022452	1.1416	0.3470861
SITE:HARV	5	0.002829	0.0005657	0.2877	0.9182761
FERT:HARV	1	0.002614	0.0026144	1.3293	0.2529605
SITE:FERT:HARV	5	0.007866	0.0015731	0.7999	0.5536222
Residuals	68	0.133733	0.0019667		

WT and SO plots Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	9.145164	1.829033	32.94762	0.0000000
FERT	1	0.747001	0.747001	13.45624	0.0004806
HARV	1	0.062088	0.062088	1.11843	0.2939984
SITE:FERT	5	1.029651	0.205930	3.70956	0.0049942
SITE:HARV	5	0.352639	0.070528	1.27047	0.2868041
FERT:HARV	1	0.045679	0.045679	0.82285	0.3675506
SITE:FERT:HARV	5	0.210089	0.042018	0.75690	0.5840000
Residuals	68	3.774908	0.055513		

WT and SO plots Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1837.684	367.5367	40.70155	0.0000000
FERT	1	7.408	7.4078	0.82035	0.3682746
HARV	1	14.303	14.3034	1.58397	0.2124930
SITE:FERT	5	15.941	3.1881	0.35306	0.8785660
SITE:HARV	5	5.966	1.1932	0.13214	0.9844761
FERT:HARV	1	8.916	8.9156	0.98733	0.3239181
SITE:FERT:HARV	5	16.548	3.3095	0.36650	0.8697911
Residuals	68	614.043	9.0300		

WT and SO plots Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.628539	0.5257078	48.86174	0.0000000
FERT	1	0.130838	0.1308375	12.16065	0.0008601
HARV	1	0.031239	0.0312393	2.90352	0.0929522
SITE:FERT	5	0.020243	0.0040486	0.37629	0.8632858
SITE:HARV	5	0.011616	0.0023233	0.21593	0.9545812
FERT:HARV	1	0.017531	0.0175315	1.62946	0.2061204
SITE:FERT:HARV	5	0.039537	0.0079074	0.73495	0.5998010
Residuals	68	0.731618	0.0107591		

WT and SO plots Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2859.989	571.9978	58.91661	0.0000000
FERT	1	252.580	252.5801	26.01612	0.0000029
HARV	1	12.555	12.5548	1.29316	0.2594576
SITE:FERT	5	185.656	37.1313	3.82457	0.0041146
SITE:HARV	5	106.046	21.2092	2.18457	0.0659466
FERT:HARV	1	15.647	15.6467	1.61163	0.2085900
SITE:FERT:HARV	5	123.806	24.7611	2.55043	0.0356250
Residuals	68	660.185	9.7086		

1.8.2: WT and SO HARVESTING AT ALL SITES SUMMER 2003

WT and SO plots FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3.338686	0.6677372	280.3568	0.0000000
FERT	1	0.012113	0.0121128	5.0857	0.0273467
HARV	1	0.000286	0.0002860	0.1201	0.7300050
SITE:FERT	5	0.028567	0.0057134	2.3988	0.0460195
SITE:HARV	5	0.041022	0.0082043	3.4447	0.0078141
FERT:HARV	1	0.002824	0.0028241	1.1857	0.2800396
SITE:FERT:HARV	5	0.015323	0.0030646	1.2867	0.2798743
Residuals	68	0.161958	0.0023817		

WT and SO plots FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	50.56572	10.11314	10.37644	0.0000002
FERT	1	48.39062	48.39062	49.65049	0.0000000
HARV	1	18.75976	18.75976	19.24818	0.0000409
SITE:FERT	5	13.41633	2.68327	2.75313	0.0252691
SITE:HARV	5	8.67412	1.73482	1.77999	0.1286528
FERT:HARV	1	0.42501	0.42501	0.43608	0.5112528
SITE:FERT:HARV	5	4.20103	0.84021	0.86208	0.5111987
Residuals	68	66.27452	0.97463		

WT and SO plots FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	190916.3	38183.27	28.76367	0.0000000
FERT	1	2897.2	2897.19	2.18247	0.1442073
HARV	1	105.7	105.74	0.07966	0.7786201
SITE:FERT	5	3617.0	723.40	0.54494	0.7415578
SITE:HARV	5	8069.0	1613.81	1.21569	0.3112729
FERT:HARV	1	2160.3	2160.27	1.62734	0.2064115
SITE:FERT:HARV	5	5681.4	1136.28	0.85596	0.5152853
Residuals	68	90268.8	1327.48		

WT and SO plots FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	269.2770	53.85540	4.680005	0.0009896
FERT	1	24.6201	24.62013	2.139475	0.1481578
HARV	1	0.6927	0.69270	0.060195	0.8069268
SITE:FERT	5	30.0890	6.01779	0.522943	0.7580748
SITE:HARV	5	34.2268	6.84536	0.594858	0.7039133
FERT:HARV	1	71.4641	71.46408	6.210189	0.0151447
SITE:FERT:HARV	5	25.9218	5.18436	0.450518	0.8114771
Residuals	68	782.5136	11.50755		

WT and SO plots FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.891676	0.3783352	9.073022	0.0000012
FERT	1	0.154278	0.1542779	3.699807	0.0586064
HARV	1	0.001620	0.0016195	0.038838	0.8443574
SITE:FERT	5	0.426589	0.0853179	2.046045	0.0830678
SITE:HARV	5	0.020637	0.0041274	0.098980	0.9919802
FERT:HARV	1	0.002064	0.0020642	0.049503	0.8245967
SITE:FERT:HARV	5	0.118358	0.0236715	0.567677	0.7244273
Residuals	68	2.835527	0.0416989		

WT and SO plots mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	11.72630	2.34526	10.81534	0.0000001
FERT	1	10.81221	10.81221	49.86133	0.0000000
HARV	1	3.93329	3.93329	18.13865	0.0000646
SITE:FERT	5	2.93817	0.58763	2.70992	0.0271909
SITE:HARV	5	1.78547	0.35709	1.64676	0.1595401
FERT:HARV	1	0.00843	0.00843	0.03889	0.8442500
SITE:FERT:HARV	5	0.89359	0.17872	0.82417	0.5368312
Residuals	68	14.74550	0.21685		

WT and SO plots mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.00580694	0.001161389	6.57841	0.0000477
FERT	1	0.00841457	0.008414568	47.66229	0.0000000
HARV	1	0.00220010	0.002200097	12.46192	0.0007504
SITE:FERT	5	0.00321516	0.000643033	3.64230	0.0055944
SITE:HARV	5	0.00085536	0.000171071	0.96899	0.4430699
FERT:HARV	1	0.00004787	0.000047872	0.27116	0.6042485
SITE:FERT:HARV	5	0.00065670	0.000131339	0.74394	0.5933067
Residuals	68	0.01200510	0.000176546		

WT and SO plots FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	3205.315	641.0631	7.219627	0.0000179
FERT	1	1.138	1.1380	0.012816	0.9102003
HARV	1	4.464	4.4642	0.050276	0.8232560
SITE:FERT	5	528.865	105.7730	1.191212	0.3227569
SITE:HARV	5	96.240	19.2479	0.216769	0.9542108
FERT:HARV	1	83.795	83.7947	0.943693	0.3347728
SITE:FERT:HARV	5	155.495	31.0989	0.350235	0.8803862
Residuals	68	6038.025	88.7945		

WT and SO HARVESTING AT ALL SITES SUMMER 2003 continued

WT and SO plots Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.9397451	0.1879490	85.20868	0.0000000
FERT	1	0.0058965	0.0058965	2.67324	0.1066692
HARV	1	0.0332703	0.0332703	15.08343	0.0002354
SITE:FERT	5	0.0137356	0.0027471	1.24543	0.2977782
SITE:HARV	5	0.0446932	0.0089386	4.05243	0.0028068
FERT:HARV	1	0.0007086	0.0007086	0.32123	0.5727361
SITE:FERT:HARV	5	0.0016747	0.0003349	0.15184	0.9788144
Residuals	68	0.1499910	0.0022057		

1.8.3: WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003

WT and SO plots FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.649450	0.529890	280.314	0.0000000
YEAR	1	2.207005	2.207005	1167.515	0.0000000
FERT	1	0.034817	0.034817	18.418	0.0000335
HARV	1	0.000483	0.000483	0.255	0.6142126
SITE:YEAR	5	1.433150	0.286630	151.629	0.0000000
SITE:FERT	5	0.027562	0.005512	2.916	0.0155993
YEAR:FERT	1	0.000958	0.000958	0.507	0.4778142
SITE:HARV	5	0.041811	0.008362	4.424	0.0009166
YEAR:HARV	1	0.000004	0.000004	0.002	0.9642727
FERT:HARV	1	0.004330	0.004330	2.291	0.1324857
SITE:YEAR:FERT	5	0.023272	0.004654	2.462	0.0359869
SITE:YEAR:HARV	5	0.017360	0.003472	1.837	0.1097067
SITE:FERT:HARV	5	0.021722	0.004344	2.298	0.0484538
YEAR:FERT:HARV	1	0.000087	0.000087	0.046	0.8300116
SITE:YEAR:FERT:HARV	5	0.008908	0.001782	0.942	0.4557506
Residuals	136	0.257087	0.001890		

WT and SO plots FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	333.9414	66.78829	52.68629	0.0000000
YEAR	1	62.1017	62.10171	48.98926	0.0000000
FERT	1	60.7206	60.72065	47.89980	0.0000000
HARV	1	55.4725	55.47251	43.75978	0.0000000
SITE:YEAR	5	254.3699	50.87399	40.13221	0.0000000
SITE:FERT	5	10.6104	2.12207	1.67401	0.1449668
YEAR:FERT	1	4.1837	4.18366	3.30030	0.0714691
SITE:HARV	5	7.0254	1.40508	1.10841	0.3588731
YEAR:HARV	1	1.7495	1.74945	1.38006	0.2421430
FERT:HARV	1	0.2359	0.23594	0.18612	0.6668457
SITE:YEAR:FERT	5	5.6079	1.12158	0.88476	0.4932276
SITE:YEAR:HARV	5	8.1925	1.63850	1.29254	0.2707228
SITE:FERT:HARV	5	2.7811	0.55621	0.43877	0.8208038
YEAR:FERT:HARV	1	1.9816	1.98163	1.56322	0.2133410
SITE:YEAR:FERT:HARV	5	3.5668	0.71337	0.56275	0.7283968
Residuals	136	172.4017	1.26766		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT and SO plots FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	149099.0	29819.81	30.87156	0.0000000
YEAR	1	46094.9	46094.86	47.72063	0.0000000
FERT	1	15.2	15.19	0.01572	0.9004061
HARV	1	2174.3	2174.26	2.25094	0.1358508
SITE:YEAR	5	140634.9	28126.98	29.11902	0.0000000
SITE:FERT	5	10478.4	2095.67	2.16959	0.0610484
YEAR:FERT	1	5216.3	5216.30	5.40028	0.0216158
SITE:HARV	5	3867.9	773.58	0.80087	0.5508926
YEAR:HARV	1	1029.5	1029.54	1.06585	0.3037178
FERT:HARV	1	497.3	497.35	0.51489	0.4742608
SITE:YEAR:FERT	5	11285.1	2257.02	2.33663	0.0452056
SITE:YEAR:HARV	5	8301.5	1660.31	1.71887	0.1343281
SITE:FERT:HARV	5	2741.6	548.32	0.56766	0.7246553
YEAR:FERT:HARV	1	1886.1	1886.12	1.95265	0.1645773
SITE:YEAR:FERT:HARV	5	5865.8	1173.17	1.21454	0.3056301
Residuals	136	131366.7	965.93		

WT and SO plots FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2775.618	555.124	41.8912	0.0000000
YEAR	1	2038.134	2038.134	153.8032	0.0000000
FERT	1	101.877	101.877	7.6879	0.0063396
HARV	1	100.845	100.845	7.6101	0.0066036
SITE:YEAR	5	1300.630	260.126	19.6298	0.0000000
SITE:FERT	5	365.754	73.151	5.5202	0.0001166
YEAR:FERT	1	9.463	9.463	0.7141	0.3995590
SITE:HARV	5	81.879	16.376	1.2358	0.2957888
YEAR:HARV	1	78.591	78.591	5.9307	0.0161746
FERT:HARV	1	49.400	49.400	3.7279	0.0555921
SITE:YEAR:FERT	5	332.525	66.505	5.0186	0.0002987
SITE:YEAR:HARV	5	3.825	0.765	0.0577	0.9978004
SITE:FERT:HARV	5	79.169	15.834	1.1949	0.3149969
YEAR:FERT:HARV	1	24.273	24.273	1.8317	0.1781745
SITE:YEAR:FERT:HARV	5	44.193	8.839	0.6670	0.6491286
Residuals	136	1802.213	13.252		

WT and SO plots FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.407879	0.481576	16.35766	0.0000000
YEAR	1	0.313446	0.313446	10.64682	0.0013944
FERT	1	1.973836	1.973836	67.04517	0.0000000
HARV	1	0.007113	0.007113	0.24160	0.6238474
SITE:YEAR	5	1.030802	0.206160	7.00264	0.0000075
SITE:FERT	5	0.769845	0.153969	5.22985	0.0002008
YEAR:FERT	1	0.721573	0.721573	24.50964	0.0000022
SITE:HARV	5	0.124844	0.024969	0.84811	0.5179804
YEAR:HARV	1	0.019951	0.019951	0.67769	0.4118256
FERT:HARV	1	0.004542	0.004542	0.15429	0.6950852
SITE:YEAR:FERT	5	0.252846	0.050569	1.71768	0.1345990
SITE:YEAR:HARV	5	0.050607	0.010121	0.34379	0.8854905
SITE:FERT:HARV	5	0.140170	0.028034	0.95223	0.4495884
YEAR:FERT:HARV	1	0.017332	0.017332	0.58870	0.4442504
SITE:YEAR:FERT:HARV	5	0.069561	0.013912	0.47255	0.7962049
Residuals	136	4.003893	0.029440		

WT and SO plots mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	36.22589	7.24518	26.68189	0.0000000
YEAR	1	3.09510	3.09510	11.39836	0.0009586
FERT	1	17.24506	17.24506	63.50856	0.0000000
HARV	1	12.69022	12.69022	46.73441	0.0000000
SITE:YEAR	5	20.74346	4.14869	15.27842	0.0000000
SITE:FERT	5	7.06145	1.41229	5.20106	0.0002120
YEAR:FERT	1	0.24750	0.24750	0.91145	0.3414233
SITE:HARV	5	1.67080	0.33416	1.23061	0.2981528
YEAR:HARV	1	0.57395	0.57395	2.11368	0.1482915
FERT:HARV	1	0.19634	0.19634	0.72305	0.3966403
SITE:YEAR:FERT	5	1.51163	0.30233	1.11338	0.3562264
SITE:YEAR:HARV	5	2.00157	0.40031	1.47424	0.2022258
SITE:FERT:HARV	5	0.82416	0.16483	0.60702	0.6946424
YEAR:FERT:HARV	1	0.32830	0.32830	1.20902	0.2734680
SITE:YEAR:FERT:HARV	5	0.48476	0.09695	0.35704	0.8769742
Residuals	136	36.92933	0.27154		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT and SO plots mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	0.03609967	0.00721993	36.5930	0.0000000
YEAR	1	0.00468982	0.00468982	23.7696	0.0000030
FERT	1	0.02170876	0.02170876	110.0272	0.0000000
HARV	1	0.00756335	0.00756335	38.3336	0.0000000
SITE:YEAR	5	0.01955394	0.00391079	19.8212	0.0000000
SITE:FERT	5	0.01194396	0.00238879	12.1072	0.0000000
YEAR:FERT	1	0.00031017	0.00031017	1.5721	0.2120578
SITE:HARV	5	0.00102814	0.00020563	1.0422	0.3955381
YEAR:HARV	1	0.00042574	0.00042574	2.1578	0.1441556
FERT:HARV	1	0.00000174	0.00000174	0.0088	0.9252872
SITE:YEAR:FERT	5	0.00117880	0.00023576	1.1949	0.3149727
SITE:YEAR:HARV	5	0.00142328	0.00028466	1.4427	0.2128968
SITE:FERT:HARV	5	0.00062407	0.00012481	0.6326	0.6751734
YEAR:FERT:HARV	1	0.00012331	0.00012331	0.6250	0.4305806
SITE:YEAR:FERT:HARV	5	0.00056094	0.00011219	0.5686	0.7239363
Residuals	136	0.02683329	0.00019730		

WT and SO plots FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	9681.393	1936.279	31.91503	0.0000000
YEAR	1	448.472	448.472	7.39200	0.0074058
FERT	1	1045.890	1045.890	17.23904	0.0000578
HARV	1	12.741	12.741	0.21001	0.6474943
SITE:YEAR	5	1476.814	295.363	4.86837	0.0003963
SITE:FERT	5	130.330	26.066	0.42964	0.8273420
YEAR:FERT	1	950.587	950.587	15.66821	0.0001211
SITE:HARV	5	177.786	35.557	0.58608	0.7106157
YEAR:HARV	1	43.001	43.001	0.70877	0.4013305
FERT:HARV	1	11.791	11.791	0.19434	0.6600269
SITE:YEAR:FERT	5	899.296	179.859	2.96456	0.0142563
SITE:YEAR:HARV	5	24.572	4.914	0.08100	0.9950825
SITE:FERT:HARV	5	216.162	43.232	0.71259	0.6149915
YEAR:FERT:HARV	1	90.476	90.476	1.49128	0.2241306
SITE:YEAR:FERT:HARV	5	188.886	37.777	0.62267	0.6827262
Residuals	136	8251.094	60.670		

WT and SO plots Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1.678198	0.3356395	160.8850	0.0000000
YEAR	1	0.396706	0.3967056	190.1563	0.0000000
FERT	1	0.002708	0.0027078	1.2980	0.2565866
HARV	1	0.023608	0.0236079	11.3162	0.0009985
SITE:YEAR	5	0.679911	0.1359821	65.1815	0.0000000
SITE:FERT	5	0.023244	0.0046488	2.2284	0.0549458
YEAR:FERT	1	0.003199	0.0031989	1.5334	0.2177435
SITE:HARV	5	0.023904	0.0047808	2.2916	0.0490327
YEAR:HARV	1	0.010880	0.0108797	5.2151	0.0239416
FERT:HARV	1	0.003022	0.0030225	1.4488	0.2308125
SITE:YEAR:FERT	5	0.001717	0.0003434	0.1646	0.9751041
SITE:YEAR:HARV	5	0.023618	0.0047235	2.2642	0.0515205
SITE:FERT:HARV	5	0.008104	0.0016207	0.7769	0.5680035
YEAR:FERT:HARV	1	0.000300	0.0003004	0.1440	0.7049241
SITE:YEAR:FERT:HARV	5	0.001437	0.0002873	0.1377	0.9832732
Residuals	136	0.283724	0.0020862		

1.9.1: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002

WH/TARA/KIN/GD only FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.155683	0.3852276	174.9918	0.0000000
FERT	1	0.054316	0.0543156	24.6732	0.0000051
HARV	2	0.056484	0.0282418	12.8290	0.0000196
SITE:FERT	3	0.015053	0.0050176	2.2793	0.0875227
SITE:HARV	6	0.051105	0.0085174	3.8691	0.0022799
FERT:HARV	2	0.001616	0.0008082	0.3671	0.6941187
SITE:FERT:HARV	6	0.012425	0.0020708	0.9407	0.4722013
Residuals	66	0.145293	0.0022014		

WH/TARA/KIN/GD only FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	571.8523	190.6174	133.3521	0.0000000
FERT	1	20.4932	20.4932	14.3366	0.0003326
HARV	2	86.0597	43.0298	30.1028	0.0000000
SITE:FERT	3	7.8372	2.6124	1.8276	0.1506946
SITE:HARV	6	45.6376	7.6063	5.3212	0.0001580
FERT:HARV	2	1.9344	0.9672	0.6766	0.5118145
SITE:FERT:HARV	6	8.9392	1.4899	1.0423	0.4062905
Residuals	66	94.3423	1.4294		

WH/TARA/KIN/GD only FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	153243.2	51081.08	45.77060	0.0000000
FERT	1	5243.7	5243.68	4.69853	0.0338005
HARV	2	1649.8	824.92	0.73916	0.4814277
SITE:FERT	3	21846.2	7282.06	6.52501	0.0006222
SITE:HARV	6	13345.8	2224.30	1.99306	0.0791018
FERT:HARV	2	760.2	380.09	0.34058	0.7126037
SITE:FERT:HARV	6	1683.7	280.61	0.25144	0.9570460
Residuals	66	73657.6	1116.02		

WH/TARA/KIN/GD only FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	4650.417	1550.139	70.09200	0.0000000
FERT	1	278.774	278.774	12.60522	0.0007150
HARV	2	635.619	317.810	14.37026	0.0000066
SITE:FERT	3	876.647	292.216	13.21300	0.0000007
SITE:HARV	6	55.462	9.244	0.41796	0.8645371
FERT:HARV	2	19.795	9.898	0.44754	0.6411233
SITE:FERT:HARV	6	142.630	23.772	1.07487	0.3865754
Residuals	66	1459.641	22.116		

WH/TARA/KIN/GD only FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.179633	0.393211	20.2216	0.0000000
FERT	1	2.876534	2.876534	147.9313	0.0000000
HARV	2	0.119007	0.059503	3.0601	0.0535898
SITE:FERT	3	0.597142	0.199047	10.2364	0.0000127
SITE:HARV	6	0.993896	0.165649	8.5188	0.0000007
FERT:HARV	2	0.177016	0.088508	4.5517	0.0140666
SITE:FERT:HARV	6	0.048687	0.008115	0.4173	0.8649805
Residuals	66	1.283375	0.019445		

WH/TARA/KIN/GD only mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	40.05378	13.35126	48.02803	0.0000000
FERT	1	8.10509	8.10509	29.15616	0.0000010
HARV	2	19.58382	9.79191	35.22410	0.0000000
SITE:FERT	3	7.24553	2.41518	8.68803	0.0000614
SITE:HARV	6	8.18758	1.36460	4.90882	0.0003327
FERT:HARV	2	0.66790	0.33395	1.20131	0.3072909
SITE:FERT:HARV	6	0.41779	0.06963	0.25049	0.9574382
Residuals	66	18.34727	0.27799		

WH/TARA/KIN/GD only mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	0.05025298	0.01675099	90.80153	0.0000000
FERT	1	0.01335078	0.01335078	72.37011	0.0000000
HARV	2	0.01202872	0.00601436	32.60184	0.0000000
SITE:FERT	3	0.01303768	0.00434589	23.55764	0.0000000
SITE:HARV	6	0.00589623	0.00098271	5.32692	0.0001564
FERT:HARV	2	0.00045234	0.00022617	1.22598	0.3000638
SITE:FERT:HARV	6	0.00045508	0.00007585	0.41114	0.8691054
Residuals	66	0.01217563	0.00018448		

WH/TARA/KIN/GD only FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	5659.352	1886.451	52.43125	0.0000000
FERT	1	1559.074	1559.074	43.33228	0.0000000
HARV	2	286.731	143.366	3.98465	0.0232408
SITE:FERT	3	180.841	60.280	1.67540	0.1807778
SITE:HARV	6	1461.617	243.603	6.77060	0.0000127
FERT:HARV	2	103.009	51.504	1.43149	0.2462741
SITE:FERT:HARV	6	406.433	67.739	1.88271	0.0968829
Residuals	66	2374.648	35.980		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 continued

WH/TARA/KIN/GD only Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.776723	0.5922411	341.9244	0.0000000
FERT	1	0.000030	0.0000300	0.0173	0.8956575
HARV	2	0.042192	0.0210962	12.1797	0.0000315
SITE:FERT	3	0.013515	0.0045048	2.6008	0.0593929
SITE:HARV	6	0.016962	0.0028270	1.6322	0.1522044
FERT:HARV	2	0.001963	0.0009816	0.5667	0.5701316
SITE:FERT:HARV	6	0.006836	0.0011393	0.6578	0.6837699
Residuals	66	0.114317	0.0017321		

WH/TARA/KIN/GD only Soil pH

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	4.200432	1.400144	24.63711	0.0000000
FERT	1	1.011240	1.011240	17.79391	0.0000767
HARV	2	1.264882	0.632441	11.12852	0.0000684
SITE:FERT	3	1.280331	0.426777	7.50962	0.0002129
SITE:HARV	6	0.296429	0.049405	0.86933	0.5222252
FERT:HARV	2	0.165620	0.082810	1.45714	0.2402965
SITE:FERT:HARV	6	0.163997	0.027333	0.48095	0.8201978
Residuals	66	3.750825	0.056831		

WH/TARA/KIN/GD only Soil carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2036.854	678.9514	72.76997	0.0000000
FERT	1	4.886	4.8857	0.52365	0.4718466
HARV	2	258.050	129.0248	13.82887	0.0000096
SITE:FERT	3	12.152	4.0508	0.43416	0.7292528
SITE:HARV	6	72.401	12.0669	1.29333	0.2725707
FERT:HARV	2	9.670	4.8349	0.51820	0.5979927
SITE:FERT:HARV	6	18.155	3.0259	0.32432	0.9219686
Residuals	66	615.787	9.3301		

WH/TARA/KIN/GD only Soil nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3.175684	1.058561	108.2490	0.0000000
FERT	1	0.110340	0.110340	11.2834	0.0013026
HARV	2	0.326689	0.163344	16.7037	0.0000013
SITE:FERT	3	0.023240	0.007747	0.7922	0.5025781
SITE:HARV	6	0.067084	0.011181	1.1433	0.3474556
FERT:HARV	2	0.019241	0.009620	0.9838	0.3793122
SITE:FERT:HARV	6	0.038507	0.006418	0.6563	0.6849383
Residuals	66	0.645411	0.009779		

WH/TARA/KIN/GD only Soil carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1994.643	664.8811	53.13987	0.0000000
FERT	1	485.143	485.1435	38.77455	0.0000000
HARV	2	85.021	42.5103	3.39759	0.0394061
SITE:FERT	3	138.832	46.2774	3.69867	0.0159421
SITE:HARV	6	164.800	27.4666	2.19524	0.0543191
FERT:HARV	2	28.409	14.2047	1.13530	0.3275200
SITE:FERT:HARV	6	170.928	28.4879	2.27687	0.0466125
Residuals	66	825.786	12.5119		

1.9.2: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003

WH/TARA/KIN/GD only FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3.054357	1.018119	332.6367	0.0000000
FERT	1	0.003834	0.003834	1.2525	0.2671321
HARV	2	0.016308	0.008154	2.6640	0.0771528
SITE:FERT	3	0.014968	0.004989	1.6301	0.1908202
SITE:HARV	6	0.020951	0.003492	1.1408	0.3488324
FERT:HARV	2	0.002753	0.001376	0.4497	0.6397744
SITE:FERT:HARV	6	0.031147	0.005191	1.6961	0.1358211
Residuals	66	0.202010	0.003061		

WH/TARA/KIN/GD only FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	7.68209	2.56070	4.07956	0.0101599
FERT	1	32.54059	32.54059	51.84190	0.0000000
HARV	2	19.32249	9.66124	15.39177	0.0000033
SITE:FERT	3	16.04982	5.34994	8.52323	0.0000728
SITE:HARV	6	5.74022	0.95670	1.52417	0.1840356
FERT:HARV	2	0.60535	0.30267	0.48221	0.6195783
SITE:FERT:HARV	6	3.31732	0.55289	0.88083	0.5139714
Residuals	66	41.42747	0.62769		

WH/TARA/KIN/GD only FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	150769.4	50256.46	27.97486	0.0000000
FERT	1	111.3	111.29	0.06195	0.8042132
HARV	2	1045.4	522.72	0.29097	0.7484935
SITE:FERT	3	271.5	90.49	0.05037	0.9849277
SITE:HARV	6	14194.5	2365.75	1.31688	0.2621192
FERT:HARV	2	1122.0	560.99	0.31227	0.7328569
SITE:FERT:HARV	6	10335.7	1722.62	0.95888	0.4599052
Residuals	66	118568.1	1796.49		

WH/TARA/KIN/GD only FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	544.1506	181.3835	13.63282	0.0000005
FERT	1	0.3992	0.3992	0.03000	0.8630119
HARV	2	3.1892	1.5946	0.11985	0.8872459
SITE:FERT	3	18.0160	6.0053	0.45136	0.7171888
SITE:HARV	6	77.3365	12.8894	0.96877	0.4533174
FERT:HARV	2	89.3298	44.6649	3.35702	0.0408833
SITE:FERT:HARV	6	28.5499	4.7583	0.35764	0.9029346
Residuals	66	878.1246	13.3049		

WH/TARA/KIN/GD only FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.544990	0.5149966	16.33980	0.0000000
FERT	1	0.292643	0.2926427	9.28496	0.0033204
HARV	2	0.061470	0.0307352	0.97517	0.3824964
SITE:FERT	3	0.771095	0.2570317	8.15509	0.0001072
SITE:HARV	6	0.307482	0.0512471	1.62597	0.1538835
FERT:HARV	2	0.006710	0.0033552	0.10645	0.8991720
SITE:FERT:HARV	6	0.257346	0.0428911	1.36085	0.2435098
Residuals	66	2.080183	0.0315179		

WH/TARA/KIN/GD only mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.556970	0.518990	3.46809	0.0209759
FERT	1	6.943718	6.943718	46.40058	0.0000000
HARV	2	4.240316	2.120158	14.16771	0.0000076
SITE:FERT	3	3.538339	1.179446	7.88151	0.0001431
SITE:HARV	6	1.486701	0.247784	1.65578	0.1459460
FERT:HARV	2	0.179683	0.089842	0.60036	0.5515840
SITE:FERT:HARV	6	0.574571	0.095762	0.63992	0.6978558
Residuals	66	9.876716	0.149647		

WH/TARA/KIN/GD only mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	0.003224720	0.001074907	9.61632	0.0000237
FERT	1	0.007361115	0.007361115	65.85396	0.0000000
HARV	2	0.003249923	0.001624962	14.53722	0.0000059
SITE:FERT	3	0.004799086	0.001599695	14.31118	0.0000003
SITE:HARV	6	0.000568038	0.000094673	0.84696	0.5384873
FERT:HARV	2	0.000174306	0.000087153	0.77969	0.4627257
SITE:FERT:HARV	6	0.000413991	0.000068999	0.61727	0.7157057
Residuals	66	0.007377439	0.000111779		

WH/TARA/KIN/GD only FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2149.598	716.5326	9.761286	0.0000205
FERT	1	230.978	230.9779	3.146600	0.0806981
HARV	2	105.940	52.9700	0.721608	0.4897641
SITE:FERT	3	1055.753	351.9178	4.794159	0.0044095
SITE:HARV	6	599.961	99.9934	1.362205	0.2429530
FERT:HARV	2	81.308	40.6539	0.553826	0.5773944
SITE:FERT:HARV	6	365.610	60.9350	0.830115	0.5508991
Residuals	66	4844.766	73.4055		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003 continued

WH/TARA/KIN/GD only Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.102989	0.3676630	145.6784	0.0000000
FERT	1	0.004737	0.0047373	1.8771	0.1753119
HARV	2	0.093673	0.0468365	18.5580	0.0000004
SITE:FERT	3	0.002466	0.0008218	0.3256	0.8068063
SITE:HARV	6	0.045062	0.0075104	2.9758	0.0123893
FERT:HARV	2	0.002343	0.0011715	0.4642	0.6306890
SITE:FERT:HARV	6	0.015336	0.0025559	1.0127	0.4247744
Residuals	66	0.166571	0.0025238		

1.9.3: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003

WH/TARA/KIN/GD only FH moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2.656724	0.885575	336.5823	0.0000000
YEAR	1	2.293224	2.293224	871.5907	0.0000000
FERT	1	0.043505	0.043505	16.5349	0.0000816
HARV	2	0.063172	0.031586	12.0049	0.0000162
SITE:YEAR	3	1.553316	0.517772	196.7908	0.0000000
SITE:FERT	3	0.017069	0.005690	2.1625	0.0954820
YEAR:FERT	1	0.014645	0.014645	5.5660	0.0197786
SITE:HARV	6	0.038249	0.006375	2.4229	0.0296669
YEAR:HARV	2	0.009620	0.004810	1.8281	0.1647650
FERT:HARV	2	0.001582	0.000791	0.3005	0.7409191
SITE:YEAR:FERT	3	0.012952	0.004317	1.6408	0.1830279
SITE:YEAR:HARV	6	0.033807	0.005634	2.1415	0.0527502
SITE:FERT:HARV	6	0.028341	0.004724	1.7953	0.1047585
YEAR:FERT:HARV	2	0.002788	0.001394	0.5297	0.5899996
SITE:YEAR:FERT:HARV	6	0.015231	0.002538	0.9648	0.4517019
Residuals	132	0.347302	0.002631		

WH/TARA/KIN/GD only FH oven dry ash free mass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	343.7504	114.5835	111.4019	0.0000000
YEAR	1	64.8670	64.8670	63.0659	0.0000000
FERT	1	52.3405	52.3405	50.8872	0.0000000
HARV	2	93.4649	46.7325	45.4349	0.0000000
SITE:YEAR	3	235.7840	78.5947	76.4124	0.0000000
SITE:FERT	3	22.4357	7.4786	7.2709	0.0001498
YEAR:FERT	1	0.6932	0.6932	0.6740	0.4131415
SITE:HARV	6	22.2835	3.7139	3.6108	0.0023901
YEAR:HARV	2	11.9173	5.9586	5.7932	0.0038762
FERT:HARV	2	0.7032	0.3516	0.3418	0.7110973
SITE:YEAR:FERT	3	1.4514	0.4838	0.4704	0.7034566
SITE:YEAR:HARV	6	29.0943	4.8491	4.7144	0.0002218
SITE:FERT:HARV	6	5.0253	0.8376	0.8143	0.5606399
YEAR:FERT:HARV	2	1.8366	0.9183	0.8928	0.4119692
SITE:YEAR:FERT:HARV	6	7.2312	1.2052	1.1717	0.3252673
Residuals	132	135.7698	1.0286		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003 continued

WH/TARA/KIN/GD only FH density

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	135850.3	45283.45	31.09582	0.0000000
YEAR	1	82149.7	82149.68	56.41159	0.0000000
FERT	1	1913.6	1913.56	1.31403	0.2537404
HARV	2	67.5	33.74	0.02317	0.9770988
SITE:YEAR	3	168162.3	56054.10	38.49195	0.0000000
SITE:FERT	3	13067.0	4355.66	2.99100	0.0333487
YEAR:FERT	1	3441.4	3441.41	2.36319	0.1266216
SITE:HARV	6	19748.3	3291.38	2.26017	0.0414485
YEAR:HARV	2	2627.8	1313.89	0.90224	0.4081467
FERT:HARV	2	50.1	25.03	0.01719	0.9829619
SITE:YEAR:FERT	3	9050.7	3016.89	2.07168	0.1070319
SITE:YEAR:HARV	6	7792.1	1298.68	0.89179	0.5029825
SITE:FERT:HARV	6	4037.0	672.84	0.46203	0.8353336
YEAR:FERT:HARV	2	1832.1	916.06	0.62905	0.5346890
SITE:YEAR:FERT:HARV	6	7982.4	1330.39	0.91357	0.4873537
Residuals	132	192225.7	1456.26		

WH/TARA/KIN/GD only FH carbon content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3609.675	1203.225	67.9391	0.0000000
YEAR	1	2852.257	2852.257	161.0503	0.0000000
FERT	1	150.136	150.136	8.4773	0.0042231
HARV	2	346.950	173.475	9.7951	0.0001080
SITE:YEAR	3	1584.893	528.298	29.8299	0.0000000
SITE:FERT	3	541.215	180.405	10.1864	0.0000044
YEAR:FERT	1	129.038	129.038	7.2860	0.0078590
SITE:HARV	6	101.029	16.838	0.9508	0.4613187
YEAR:HARV	2	291.858	145.929	8.2398	0.0004245
FERT:HARV	2	68.260	34.130	1.9271	0.1496393
SITE:YEAR:FERT	3	353.448	117.816	6.6524	0.0003223
SITE:YEAR:HARV	6	31.769	5.295	0.2990	0.9364353
SITE:FERT:HARV	6	85.342	14.224	0.8031	0.5691803
YEAR:FERT:HARV	2	40.865	20.433	1.1537	0.3186253
SITE:YEAR:FERT:HARV	6	85.837	14.306	0.8078	0.5656114
Residuals	132	2337.766	17.710		

WH/TARA/KIN/GD only FH nitrogen content (%)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.579082	0.526361	20.65658	0.0000000
YEAR	1	0.882553	0.882553	34.63505	0.0000000
FERT	1	2.502083	2.502083	98.19215	0.0000000
HARV	2	0.170900	0.085450	3.35341	0.0379684
SITE:YEAR	3	1.145541	0.381847	14.98526	0.0000000
SITE:FERT	3	1.309971	0.436657	17.13623	0.0000000
YEAR:FERT	1	0.667094	0.667094	26.17953	0.0000011
SITE:HARV	6	0.957287	0.159548	6.26132	0.0000082
YEAR:HARV	2	0.009577	0.004789	0.18792	0.8289007
FERT:HARV	2	0.067752	0.033876	1.32943	0.2681473
SITE:YEAR:FERT	3	0.058266	0.019422	0.76221	0.5172145
SITE:YEAR:HARV	6	0.344092	0.057349	2.25060	0.0422662
SITE:FERT:HARV	6	0.099747	0.016625	0.65242	0.6880969
YEAR:FERT:HARV	2	0.115974	0.057987	2.27565	0.1067464
SITE:YEAR:FERT:HARV	6	0.206286	0.034381	1.34925	0.2399523
Residuals	132	3.363558	0.025482		

WH/TARA/KIN/GD only mass of carbon in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	26.16756	8.72252	40.79411	0.0000000
YEAR	1	2.39236	2.39236	11.18878	0.0010717
FERT	1	15.02637	15.02637	70.27642	0.0000000
HARV	2	20.99449	10.49724	49.09428	0.0000000
SITE:YEAR	3	15.44320	5.14773	24.07529	0.0000000
SITE:FERT	3	10.31449	3.43816	16.07985	0.0000000
YEAR:FERT	1	0.02244	0.02244	0.10495	0.7464804
SITE:HARV	6	4.69775	0.78296	3.66180	0.0021417
YEAR:HARV	2	2.82964	1.41482	6.61695	0.0018255
FERT:HARV	2	0.71011	0.35505	1.66054	0.1939806
SITE:YEAR:FERT	3	0.46938	0.15646	0.73175	0.5348293
SITE:YEAR:HARV	6	4.97653	0.82942	3.87910	0.0013412
SITE:FERT:HARV	6	0.34255	0.05709	0.26701	0.9513900
YEAR:FERT:HARV	2	0.13748	0.06874	0.32148	0.7256403
SITE:YEAR:FERT:HARV	6	0.64981	0.10830	0.50652	0.8025649
Residuals	132	28.22399	0.21382		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003 continued

WH/TARA/KIN/GD only mass of nitrogen in FH litter

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	0.03596404	0.01198801	80.9294	0.0000000
YEAR	1	0.00318331	0.00318331	21.4901	0.0000084
FERT	1	0.02026940	0.02026940	136.8359	0.0000000
HARV	2	0.01387295	0.00693648	46.8272	0.0000000
SITE:YEAR	3	0.01751365	0.00583788	39.4107	0.0000000
SITE:FERT	3	0.01668730	0.00556243	37.5512	0.0000000
YEAR:FERT	1	0.00044249	0.00044249	2.9872	0.0862640
SITE:HARV	6	0.00277435	0.00046239	3.1215	0.0068189
YEAR:HARV	2	0.00140569	0.00070285	4.7448	0.0102342
FERT:HARV	2	0.00046556	0.00023278	1.5715	0.2115992
SITE:YEAR:FERT	3	0.00114947	0.00038316	2.5866	0.0558188
SITE:YEAR:HARV	6	0.00368992	0.00061499	4.1517	0.0007452
SITE:FERT:HARV	6	0.00017926	0.00002988	0.2017	0.9757441
YEAR:FERT:HARV	2	0.00016108	0.00008054	0.5437	0.5818830
SITE:YEAR:FERT:HARV	6	0.00068981	0.00011497	0.7761	0.5900341
Residuals	132	0.01955307	0.00014813		

WH/TARA/KIN/GD only FH carbon: nitrogen ratio

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	7047.243	2349.081	42.95067	0.0000000
YEAR	1	300.963	300.963	5.50281	0.0204755
FERT	1	1495.119	1495.119	27.33681	0.0000007
HARV	2	109.600	54.800	1.00196	0.3699328
SITE:YEAR	3	761.707	253.902	4.64236	0.0040499
SITE:FERT	3	249.903	83.301	1.52308	0.2115026
YEAR:FERT	1	294.933	294.933	5.39257	0.0217533
SITE:HARV	6	1270.070	211.678	3.87033	0.0013668
YEAR:HARV	2	283.072	141.536	2.58785	0.0789928
FERT:HARV	2	84.631	42.316	0.77370	0.4633827
SITE:YEAR:FERT	3	986.691	328.897	6.01356	0.0007158
SITE:YEAR:HARV	6	791.508	131.918	2.41199	0.0303427
SITE:FERT:HARV	6	341.830	56.972	1.04167	0.4013488
YEAR:FERT:HARV	2	99.685	49.842	0.91132	0.4045070
SITE:YEAR:FERT:HARV	6	430.213	71.702	1.31101	0.2565916
Residuals	132	7219.414	54.693		

WH/TARA/KIN/GD only Soil moisture content

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2.086814	0.6956047	326.8911	0.0000000
YEAR	1	0.467774	0.4677741	219.8248	0.0000000
FERT	1	0.002007	0.0020065	0.9429	0.3332966
HARV	2	0.117673	0.0588363	27.6494	0.0000000
SITE:YEAR	3	0.792898	0.2642994	124.2043	0.0000000
SITE:FERT	3	0.013705	0.0045684	2.1469	0.0973745
YEAR:FERT	1	0.002761	0.0027608	1.2974	0.2567511
SITE:HARV	6	0.021390	0.0035650	1.6753	0.1318681
YEAR:HARV	2	0.018193	0.0090964	4.2747	0.0158909
FERT:HARV	2	0.003945	0.0019727	0.9271	0.3982799
SITE:YEAR:FERT	3	0.002275	0.0007582	0.3563	0.7846341
SITE:YEAR:HARV	6	0.040634	0.0067723	3.1826	0.0059862
SITE:FERT:HARV	6	0.014346	0.0023910	1.1236	0.3520515
YEAR:FERT:HARV	2	0.000361	0.0001803	0.0848	0.9187894
SITE:YEAR:FERT:HARV	6	0.007825	0.0013042	0.6129	0.7196587
Residuals	132	0.280888	0.0021279		

STATISTICAL APPENDIX TWO: FH Litter Biomass, Soil Microbial Biomass and Nitrogen Mineralisation ANOVA Outputs

2.1.1: WOODHILL SUMMER 2002

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	73.572	73.572	0.137551	0.7171925
HARV	2	3023.705	1511.853	2.826573	0.0986631
FERT:HARV	2	1082.340	541.170	1.011776	0.3925900
Residuals	12	6418.455	534.871		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.142547	0.1425471	0.263911	0.6167732
HARV	2	1.437238	0.7186190	1.330449	0.3006935
FERT:HARV	2	0.725467	0.3627333	0.671563	0.5291050
Residuals	12	6.481593	0.5401327		

2.1.2: WOODHILL SUMMER 2003

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4957.33	4957.334	2.577185	0.1343930
HARV	2	4631.67	2315.834	1.203940	0.3338006
FERT:HARV	2	2399.66	1199.830	0.623760	0.5524337
Residuals	12	23082.55	1923.546		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	77.0355	77.03547	5.337229	0.03945872
HARV	2	185.0981	92.54903	6.412051	0.01275987
FERT:HARV	2	102.3796	51.18982	3.546571	0.06163438
Residuals	12	173.2033	14.43361		

2.1.3: WOODHILL WINTER 2002

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2371.08	2371.075	2.781720	0.1212087
HARV	2	823.09	411.546	0.482821	0.6285262
FERT:HARV	2	319.48	159.740	0.187405	0.8314883
Residuals	12	10228.53	852.377		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	44.0086	44.0086	4.161764	0.0639863
HARV	2	205.5059	102.7530	9.717045	0.0030952
FERT:HARV	2	5.4947	2.7474	0.259811	0.7754256
Residuals	12	126.8941	10.5745		

2.1.4: WOODHILL WINTER 2003

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	6474.681	6474.681	9.015354	0.0110142
HARV	2	1903.702	951.851	1.325358	0.3019495
FERT:HARV	2	3522.523	1761.262	2.452383	0.1279477
Residuals	12	8618.205	718.184		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	49.4005	49.40054	4.117381	0.0652279
HARV	2	158.3811	79.19056	6.600287	0.0116580
FERT:HARV	2	13.1871	6.59353	0.549550	0.5910696
Residuals	12	143.9766	11.99805		

2.1.5: WOODHILL SUMMER 2002 and 2003

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	159241.6	159241.6	129.5480	0.0000000
FERT	1	3119.4	3119.4	2.5377	0.1242425
HARV	2	358.1	179.1	0.1457	0.8651966
YEAR:FERT	1	1911.5	1911.5	1.5551	0.2244184
YEAR:HARV	2	7297.2	3648.6	2.9683	0.0704882
FERT:HARV	2	384.9	192.5	0.1566	0.8559338
YEAR:FERT:HARV	2	3097.1	1548.5	1.2598	0.3018128
Residuals	24	29501.0	1229.2		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	713.8217	713.8217	95.34314	0.00000000
FERT	1	35.2752	35.2752	4.71161	0.04007722
HARV	2	76.9618	38.4809	5.13978	0.01387109
YEAR:FERT	1	41.9028	41.9028	5.59684	0.02641169
YEAR:HARV	2	109.5735	54.7867	7.31771	0.00330147
FERT:HARV	2	51.2497	25.6248	3.42264	0.04923470
YEAR:FERT:HARV	2	51.8554	25.9277	3.46309	0.04771109
Residuals	24	179.6849	7.4869		

2.1.6: WOODHILL WINTER 2002 and 2003

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	9035.38	9035.385	11.50593	0.0024042
FERT	1	8341.03	8341.035	10.62173	0.0033275
HARV	2	2314.27	1157.133	1.47353	0.2491144
YEAR:FERT	1	504.72	504.721	0.64273	0.4305918
YEAR:HARV	2	412.53	206.263	0.26266	0.7711840
FERT:HARV	2	2974.40	1487.200	1.89385	0.1723080
YEAR:FERT:HARV	2	867.60	433.802	0.55242	0.5827025
Residuals	24	18846.73	785.281		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	36.7035	36.7035	3.25205	0.0839041
FERT	1	93.3313	93.3313	8.26945	0.0083222
HARV	2	361.7046	180.8523	16.02409	0.0000380
YEAR:FERT	1	0.0779	0.0779	0.00690	0.9344877
YEAR:HARV	2	2.1825	1.0912	0.09669	0.9081923
FERT:HARV	2	4.1801	2.0900	0.18518	0.8321272
YEAR:FERT:HARV	2	14.5017	7.2509	0.64245	0.5348108
Residuals	24	270.8707	11.2863		

2.1.7: SUMMER and WINTER (2002 and 2003)

Woodhill FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	118.7	118.7	0.1179	0.7328704
YEAR	1	46206.8	46206.8	45.8745	0.0000000
FERT	1	10831.1	10831.1	10.7532	0.0019415
HARV	2	1333.6	666.8	0.6620	0.5204725
SEASON:YEAR	1	122070.1	122070.1	121.1921	0.0000000
SEASON:FERT	1	629.3	629.3	0.6248	0.4331519
YEAR:FERT	1	2190.4	2190.4	2.1746	0.1468344
SEASON:HARV	2	1338.8	669.4	0.6646	0.5191464
YEAR:HARV	2	5408.4	2704.2	2.6848	0.0784777
FERT:HARV	2	1695.5	847.7	0.8416	0.4372633
SEASON:YEAR:FERT	1	225.9	225.9	0.2243	0.6379566
SEASON:YEAR:HARV	2	2301.3	1150.7	1.1424	0.3275771
SEASON:FERT:HARV	2	1663.8	831.9	0.8259	0.4439485
YEAR:FERT:HARV	2	772.4	386.2	0.3834	0.6836005
SEASON:YEAR:FERT:HARV	2	3192.3	1596.1	1.5847	0.2155533
Residuals	48	48347.7	1007.2		

Woodhill Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	378.3481	378.3481	40.30737	0.0000001
YEAR	1	213.3992	213.3992	22.73451	0.0000177
FERT	1	121.6816	121.6816	12.96337	0.0007509
HARV	2	386.0613	193.0307	20.56455	0.0000004
SEASON:YEAR	1	537.1261	537.1261	57.22280	0.0000000
SEASON:FERT	1	6.9248	6.9248	0.73774	0.3946553
YEAR:FERT	1	22.7968	22.7968	2.42866	0.1257045
SEASON:HARV	2	52.6051	26.3025	2.80214	0.0706319
YEAR:HARV	2	43.1970	21.5985	2.30100	0.1111053
FERT:HARV	2	13.2572	6.6286	0.70618	0.4985824
SEASON:YEAR:FERT	1	19.1839	19.1839	2.04376	0.1593082
SEASON:YEAR:HARV	2	68.5589	34.2795	3.65197	0.0333922
SEASON:FERT:HARV	2	42.1726	21.0863	2.24643	0.1167839
YEAR:FERT:HARV	2	12.7402	6.3701	0.67864	0.5121076
SEASON:YEAR:FERT:HARV	2	53.6170	26.8085	2.85605	0.0673070
Residuals	48	450.5555	9.3866		

2.2.1: TARAWERA SUMMER 2002

Tarawera FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	6864.083	6864.083	28.68552	0.0000433
HARV	2	935.629	467.815	1.95503	0.1704746
FERT:HARV	2	2707.804	1353.902	5.65806	0.0124021
Residuals	18	4307.173	239.287		

Tarawera Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	19.5038	19.50377	2.810838	0.1109106
HARV	2	110.1390	55.06951	7.936489	0.0033789
FERT:HARV	2	9.5449	4.77245	0.687795	0.5154163
Residuals	18	124.8980	6.93878		

2.2.2: TARAWERA SUMMER 2003

Tarawera FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	8.643	8.6430	0.055702	0.8160875
HARV	2	201.209	100.6043	0.648367	0.5346851
FERT:HARV	2	581.360	290.6799	1.873353	0.1823523
Residuals	18	2792.981	155.1656		

Tarawera Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	81.7406	81.7406	1.966755	0.1778042
HARV	2	397.5703	198.7852	4.782955	0.0215825
FERT:HARV	2	2.7121	1.3561	0.032628	0.9679556
Residuals	18	748.1010	41.5612		

2.2.3: TARAWERA SUMMER 2002 and 2003

Tarawera FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	46379.59	46379.59	235.1590	0.0000000
FERT	1	3679.93	3679.93	18.6584	0.0001175
HARV	2	307.47	153.73	0.7795	0.4662312
YEAR:FERT	1	3192.79	3192.79	16.1885	0.0002815
YEAR:HARV	2	829.37	414.68	2.1026	0.1368900
FERT:HARV	2	2639.09	1319.55	6.6905	0.0033835
YEAR:FERT:HARV	2	650.07	325.04	1.6480	0.2066145
Residuals	36	7100.15	197.23		

Tarawera Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	8882.293	8882.293	366.2806	0.0000000
FERT	1	10.694	10.694	0.4410	0.5108733
HARV	2	462.976	231.488	9.5459	0.0004719
YEAR:FERT	1	90.550	90.550	3.7340	0.0612126
YEAR:HARV	2	44.734	22.367	0.9223	0.4067762
FERT:HARV	2	7.352	3.676	0.1516	0.8598868
YEAR:FERT:HARV	2	4.905	2.452	0.1011	0.9040684
Residuals	36	872.999	24.250		

2.3.1: BERWICK SUMMER 2002

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	31062.56	31062.56	27.74847	0.0001986
HARV	1	300.44	300.44	0.26839	0.6138323
FERT:HARV	1	1123.68	1123.68	1.00379	0.3361695
Residuals	12	13433.20	1119.43		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	97.8987	97.89866	3.670479	0.0795110
HARV	1	6.0610	6.06104	0.227245	0.6421376
FERT:HARV	1	10.4735	10.47346	0.392678	0.5426329
Residuals	12	320.0628	26.67190		

2.3.2: BERWICK SUMMER 2003

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	32808.47	32808.47	6.264956	0.0277627
HARV	1	10384.45	10384.45	1.982967	0.1844551
FERT:HARV	1	6706.01	6706.01	1.280548	0.2799047
Residuals	12	62841.88	5236.82		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	12.2542	12.25419	0.574491	0.4631055
HARV	1	23.0369	23.03691	1.079999	0.3191849
FERT:HARV	1	34.0559	34.05586	1.596581	0.2303848
Residuals	12	255.9660	21.33050		

2.3.3: BERWICK WINTER 2002

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	3413.32	3413.315	0.6780143	0.4263333
HARV	1	65.87	65.872	0.0130846	0.9108219
FERT:HARV	1	2209.89	2209.886	0.4389674	0.5201439
Residuals	12	60411.38	5034.282		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	24.1645	24.16449	2.846400	0.1173777
HARV	1	8.0781	8.07812	0.951543	0.3485818
FERT:HARV	1	0.8021	0.80211	0.094482	0.7638234
Residuals	12	101.8739	8.48949		

2.3.4: BERWICK WINTER 2002

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2136.48	2136.481	0.5985606	0.4540998
HARV	1	326.24	326.243	0.0914009	0.7675797
FERT:HARV	1	893.41	893.410	0.2502993	0.6259130
Residuals	12	42832.39	3569.366		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	205.3793	205.3793	8.724143	0.0120618
HARV	1	40.4946	40.4946	1.720140	0.2142144
FERT:HARV	1	1.2871	1.2871	0.054675	0.8190605
Residuals	12	282.4978	23.5415		

2.3.5: BERWICK SUMMER 2002 and 2003

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	7748.02	7748.02	2.43792	0.1315240
FERT	1	63859.10	63859.10	20.09330	0.0001548
HARV	1	3576.11	3576.11	1.12523	0.2993549
YEAR:FERT	1	11.93	11.93	0.00375	0.9516465
YEAR:HARV	1	7108.78	7108.78	2.23678	0.1477958
FERT:HARV	1	6659.91	6659.91	2.09555	0.1606666
YEAR:FERT:HARV	1	1169.77	1169.77	0.36807	0.5497549
Residuals	24	76275.08	3178.13		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1.8647	1.86473	0.077693	0.7828361
FERT	1	89.7127	89.71266	3.737841	0.0650733
HARV	1	26.3654	26.36540	1.098503	0.3050356
YEAR:FERT	1	20.4402	20.44019	0.851632	0.3652762
YEAR:HARV	1	2.7326	2.73256	0.113851	0.7387350
FERT:HARV	1	3.3786	3.37861	0.140769	0.7108136
YEAR:FERT:HARV	1	41.1507	41.15071	1.714527	0.2027967
Residuals	24	576.0288	24.00120		

2.3.6: BERWICK WINTER 2002 and 2003

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	25880.7	25880.71	6.016217	0.0218230
FERT	1	5475.4	5475.36	1.272799	0.2703944
HARV	1	342.7	342.65	0.079653	0.7801879
YEAR:FERT	1	74.4	74.44	0.017304	0.8964413
YEAR:HARV	1	49.5	49.46	0.011498	0.9154990
FERT:HARV	1	146.5	146.54	0.034064	0.8551211
YEAR:FERT:HARV	1	2956.8	2956.76	0.687326	0.4152449
Residuals	24	103243.8	4301.82		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	194.5235	194.5235	12.14596	0.0019115
FERT	1	185.2196	185.2196	11.56503	0.0023533
HARV	1	42.3729	42.3729	2.64574	0.1168877
YEAR:FERT	1	44.3241	44.3241	2.76758	0.1091967
YEAR:HARV	1	6.1999	6.1999	0.38712	0.5396841
FERT:HARV	1	2.0607	2.0607	0.12867	0.7229519
YEAR:FERT:HARV	1	0.0285	0.0285	0.00178	0.9666771
Residuals	24	384.3717	16.0155		

2.3.7: BERWICK SUMMER and WINTER (2002 and 2003)

Berwick FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	2082.4	2082.42	0.55680	0.4591916
YEAR	1	2653.7	2653.70	0.70955	0.4037706
FERT	1	53366.2	53366.20	14.26913	0.0004372
HARV	1	3066.3	3066.34	0.81988	0.3697371
SEASON:YEAR	1	30975.0	30975.03	8.28215	0.0059600
SEASON:FERT	1	15968.3	15968.26	4.26962	0.0442184
YEAR:FERT	1	13.4	13.38	0.00358	0.9525504
SEASON:HARV	1	852.4	852.42	0.22792	0.6352363
YEAR:HARV	1	4172.1	4172.09	1.11554	0.2961678
FERT:HARV	1	4391.1	4391.12	1.17410	0.2839727
SEASON:YEAR:FERT	1	73.0	72.99	0.01952	0.8894814
SEASON:YEAR:HARV	1	2986.1	2986.15	0.79844	0.3760183
SEASON:FERT:HARV	1	2415.3	2415.33	0.64582	0.4255747
YEAR:FERT:HARV	1	203.5	203.50	0.05441	0.8165493
SEASON:YEAR:FERT:HARV	1	3923.0	3923.03	1.04895	0.3108840
Residuals	48	179518.8	3739.98		

Berwick Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	217.6445	217.6445	10.87769	0.0018380
YEAR	1	117.2397	117.2397	5.85954	0.0193253
FERT	1	266.3713	266.3713	13.31301	0.0006487
HARV	1	67.7933	67.7933	3.38825	0.0718483
SEASON:YEAR	1	79.1486	79.1486	3.95578	0.0524271
SEASON:FERT	1	8.5610	8.5610	0.42787	0.5161580
YEAR:FERT	1	2.2824	2.2824	0.11407	0.7370254
SEASON:HARV	1	0.9449	0.9449	0.04723	0.8288826
YEAR:HARV	1	8.5823	8.5823	0.42893	0.5156390
FERT:HARV	1	0.0810	0.0810	0.00405	0.9495203
SEASON:YEAR:FERT	1	62.4819	62.4819	3.12279	0.0835617
SEASON:YEAR:HARV	1	0.3502	0.3502	0.01750	0.8952997
SEASON:FERT:HARV	1	5.3583	5.3583	0.26780	0.6071867
YEAR:FERT:HARV	1	19.5059	19.5059	0.97489	0.3284152
SEASON:YEAR:FERT:HARV	1	21.6733	21.6733	1.08322	0.3031935
Residuals	48	960.4005	20.0083		

2.4.1: BURNHAM SUMMER 2002

Burnham FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4711.717	4711.717	19.31985	0.0008723
HARV	1	256.797	256.797	1.05296	0.3250663
FERT:HARV	1	110.690	110.690	0.45387	0.5132697
Residuals	12	2926.555	243.880		

Burnham Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	11.68529	11.68529	4.996922	0.0451713
HARV	1	1.86297	1.86297	0.796652	0.3896442
FERT:HARV	1	1.84437	1.84437	0.788701	0.3919468
Residuals	12	28.06198	2.33850		

2.4.2: BURNHAM SUMMER 2002

Burnham FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1900.946	1900.946	3.758462	0.0764200
HARV	1	2.067	2.067	0.004087	0.9500764
FERT:HARV	1	420.751	420.751	0.831889	0.3796857
Residuals	12	6069.333	505.778		

Burnham Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	18.99040	18.99040	3.854218	0.0732202
HARV	1	22.99869	22.99869	4.667725	0.0516659
FERT:HARV	1	0.74559	0.74559	0.151321	0.7040905
Residuals	12	59.12608	4.92717		

2.4.3: BURNHAM SUMMER 2002 and 2003

Burnham FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	13461.20	13461.20	35.91294	0.0000035
FERT	1	6299.11	6299.11	16.80530	0.0004097
HARV	1	152.47	152.47	0.40678	0.5296471
YEAR:FERT	1	313.55	313.55	0.83652	0.3694907
YEAR:HARV	1	106.39	106.39	0.28384	0.5990946
FERT:HARV	1	49.91	49.91	0.13316	0.7183722
YEAR:FERT:HARV	1	481.53	481.53	1.28466	0.2682298
Residuals	24	8995.89	374.83		

Burnham Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	9.72137	9.72137	2.675971	0.1149219
FERT	1	30.23444	30.23444	8.322544	0.0081442
HARV	1	18.97651	18.97651	5.223607	0.0314112
YEAR:FERT	1	0.44126	0.44126	0.121463	0.7304914
YEAR:HARV	1	5.88516	5.88516	1.619989	0.2152855
FERT:HARV	1	0.12232	0.12232	0.033670	0.8559523
YEAR:FERT:HARV	1	2.46764	2.46764	0.679261	0.4179572
Residuals	24	87.18806	3.63284		

2.5.1: KINLEITH SUMMER 2002

Kinleith FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	7525.08	7525.082	5.268838	0.0339429
HARV	2	1561.53	780.763	0.546667	0.5881888
FERT:HARV	2	8473.01	4236.506	2.966275	0.0770108
Residuals	18	25708.04	1428.224		

Kinleith Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	193.2390	193.2390	9.940576	0.0055036
HARV	2	127.6662	63.8331	3.283695	0.0608445
FERT:HARV	2	51.4390	25.7195	1.323060	0.2910092
Residuals	18	349.9094	19.4394		

2.5.2: KINLEITH SUMMER 2003

Kinleith FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1542.86	1542.864	2.196939	0.1555810
HARV	2	1625.69	812.843	1.157436	0.3366090
FERT:HARV	2	634.15	317.076	0.451496	0.6436913
Residuals	18	12641.02	702.279		

Kinleith Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	793.026	793.0255	9.81979	0.0057404
HARV	2	1954.557	977.2785	12.10134	0.0004671
FERT:HARV	2	356.564	178.2821	2.20761	0.1388561
Residuals	18	1453.642	80.7579		

2.5.3: KINLEITH SUMMER 2002 and 2003

Kinleith FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	10588.80	10588.80	9.940185	0.0032545
FERT	1	1126.60	1126.60	1.057592	0.3106254
HARV	2	2543.95	1271.98	1.194063	0.3147029
YEAR:FERT	1	7941.34	7941.34	7.454900	0.0097315
YEAR:HARV	2	643.26	321.63	0.301927	0.7412458
FERT:HARV	2	6221.80	3110.90	2.920345	0.0667830
YEAR:FERT:HARV	2	2885.36	1442.68	1.354309	0.2709611
Residuals	36	38349.06	1065.25		

Kinleith Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	8689.850	8689.850	173.4547	0.0000000
FERT	1	884.595	884.595	17.6571	0.0001665
HARV	2	1428.511	714.256	14.2570	0.0000275
YEAR:FERT	1	101.669	101.669	2.0294	0.1628956
YEAR:HARV	2	653.712	326.856	6.5242	0.0038210
FERT:HARV	2	338.605	169.303	3.3794	0.0451848
YEAR:FERT:HARV	2	69.398	34.699	0.6926	0.5068089
Residuals	36	1803.552	50.099		

2.6.1: GOLDEN DOWNS SUMMER 2002

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4885.16	4885.159	1.528907	0.2321683
HARV	2	2426.69	1213.343	0.379740	0.6893909
FERT:HARV	2	411.26	205.629	0.064355	0.9378864
Residuals	18	57513.56	3195.198		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	36.1321	36.1321	0.912944	0.3519918
HARV	2	382.4012	191.2006	4.831036	0.0209166
FERT:HARV	2	11.9695	5.9847	0.151215	0.8607433
Residuals	18	712.3961	39.5776		

2.6.2: GOLDEN DOWNS SUMMER 2003

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	102.553	102.5525	1.073202	0.3139412
HARV	2	66.801	33.4003	0.349531	0.7096991
FERT:HARV	2	16.177	8.0886	0.084646	0.9192009
Residuals	18	1720.035	95.5575		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	13.3024	13.3024	0.410154	0.5299605
HARV	2	290.7930	145.3965	4.483038	0.0263083
FERT:HARV	2	18.5254	9.2627	0.285599	0.7549068
Residuals	18	583.7865	32.4326		

2.6.3: GOLDEN DOWNS WINTER 2002

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	828.24	828.239	0.707490	0.4113138
HARV	2	4322.81	2161.404	1.846290	0.1864883
FERT:HARV	2	348.41	174.205	0.148807	0.8627846
Residuals	18	21072.13	1170.674		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	949.40	949.401	1.354148	0.2597481
HARV	2	5534.95	2767.476	3.947303	0.0378938
FERT:HARV	2	1356.55	678.273	0.967433	0.3989630
Residuals	18	12619.90	701.105		

2.6.4: GOLDEN DOWNS WINTER 2003

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	13670.86	13670.86	5.733661	0.0277378
HARV	2	3910.75	1955.37	0.820098	0.4561842
FERT:HARV	2	9184.20	4592.10	1.925962	0.1746005
Residuals	18	42917.70	2384.32		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1053.03	1053.033	1.167720	0.2941366
HARV	2	6127.11	3063.556	3.397211	0.0560101
FERT:HARV	2	3477.88	1738.938	1.928328	0.1742606
Residuals	18	16232.14	901.786		

2.6.5: GOLDEN DOWNS SUMMER 2002 and 2003

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	346087.2	346087.2	210.3391	0.0000000
FERT	1	1786.1	1786.1	1.0855	0.3044177
HARV	2	1642.4	821.2	0.4991	0.6112223
YEAR:FERT	1	3201.7	3201.7	1.9459	0.1715823
YEAR:HARV	2	851.1	425.6	0.2586	0.7735262
FERT:HARV	2	132.5	66.2	0.0403	0.9605916
YEAR:FERT:HARV	2	295.0	147.5	0.0896	0.9144650
Residuals	36	59233.6	1645.4		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	38.876	38.8756	1.079725	0.3056881
FERT	1	46.641	46.6408	1.295395	0.2625742
HARV	2	609.727	304.8637	8.467244	0.0009686
YEAR:FERT	1	2.794	2.7937	0.077591	0.7821824
YEAR:HARV	2	63.467	31.7334	0.881359	0.4229670
FERT:HARV	2	28.993	14.4965	0.402622	0.6715374
YEAR:FERT:HARV	2	1.502	0.7510	0.020858	0.9793700
Residuals	36	1296.183	36.0051		

2.6.6: GOLDEN DOWNS WINTER 2002 and 2003

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	95308.82	95308.82	53.61974	0.0000000
FERT	1	10614.48	10614.48	5.97159	0.0195700
HARV	2	450.64	225.32	0.12676	0.8813331
YEAR:FERT	1	3884.62	3884.62	2.18545	0.1480175
YEAR:HARV	2	7782.91	3891.45	2.18929	0.1266852
FERT:HARV	2	6122.89	3061.45	1.72234	0.1930429
YEAR:FERT:HARV	2	3409.72	1704.86	0.95914	0.3927999
Residuals	36	63989.82	1777.50		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1350.24	1350.243	1.684760	0.2025481
FERT	1	2001.09	2001.092	2.496854	0.1228215
HARV	2	11648.76	5824.382	7.267347	0.0022327
YEAR:FERT	1	1.34	1.342	0.001674	0.9675888
YEAR:HARV	2	13.30	6.649	0.008296	0.9917398
FERT:HARV	2	4569.66	2284.829	2.850886	0.0709029
YEAR:FERT:HARV	2	264.76	132.381	0.165178	0.8483814
Residuals	36	28852.04	801.445		

2.6.7: GOLDEN DOWNS SUMMER and WINTER (2002 and 2003)

Golden Downs FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	3773.4	3773.4	2.2048	0.1419458
YEAR	1	39079.8	39079.8	22.8345	0.0000091
FERT	1	1846.2	1846.2	1.0787	0.3024563
HARV	2	651.3	325.7	0.1903	0.8271407
SEASON:YEAR	1	402316.2	402316.2	235.0752	0.0000000
SEASON:FERT	1	10554.3	10554.3	6.1670	0.0153456
YEAR:FERT	1	7069.8	7069.8	4.1309	0.0457959
SEASON:HARV	2	1441.7	720.9	0.4212	0.6578656
YEAR:HARV	2	1861.2	930.6	0.5437	0.5829350
FERT:HARV	2	2977.2	1488.6	0.8698	0.4233896
SEASON:YEAR:FERT	1	16.5	16.5	0.0096	0.9220692
SEASON:YEAR:HARV	2	6772.8	3386.4	1.9787	0.1456953
SEASON:FERT:HARV	2	3278.1	1639.1	0.9577	0.3886045
YEAR:FERT:HARV	2	1726.5	863.2	0.5044	0.6059866
SEASON:YEAR:FERT:HARV	2	1978.2	989.1	0.5779	0.5636356
Residuals	72	123223.4	1711.4		

Golden Downs Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SEASON	1	33299.25	33299.25	79.52530	0.0000000
YEAR	1	465.45	465.45	1.11159	0.2952627
FERT	1	1329.37	1329.37	3.17480	0.0789989
HARV	2	8791.63	4395.82	10.49809	0.0000998
SEASON:YEAR	1	923.67	923.67	2.20591	0.1418483
SEASON:FERT	1	718.36	718.36	1.71559	0.1944250
YEAR:FERT	1	0.13	0.13	0.00031	0.9859028
SEASON:HARV	2	3466.86	1733.43	4.13978	0.0198697
YEAR:HARV	2	13.95	6.97	0.01666	0.9834841
FERT:HARV	2	2599.59	1299.80	3.10417	0.0509164
SEASON:YEAR:FERT	1	4.00	4.00	0.00956	0.9223751
SEASON:YEAR:HARV	2	62.82	31.41	0.07501	0.9278089
SEASON:FERT:HARV	2	1999.06	999.53	2.38708	0.0991353
YEAR:FERT:HARV	2	148.15	74.07	0.17690	0.8382246
SEASON:YEAR:FERT:HARV	2	118.12	59.06	0.14104	0.8686902
Residuals	72	30148.22	418.73		

2.7.1: FERTILISATION AT ALL SITES SUMMER 2002

All Sites FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	282655.1	56531.01	46.85342	0.00000000
FERT	1	3510.6	3510.58	2.90960	0.09087587
SITE:FERT	5	51611.6	10322.32	8.55523	0.00000072
Residuals	110	132720.5	1206.55		

All Sites Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2886.457	577.2915	28.13094	0.0000000
FERT	1	9.831	9.8306	0.47904	0.4903169
SITE:FERT	5	348.771	69.7541	3.39906	0.0068000
Residuals	110	2257.374	20.5216		

2.7.2: FERTILISATION AT ALL SITES SUMMER 2003

All Sites FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	484498.6	96899.71	77.90631	0.000000000
FERT	1	17330.8	17330.80	13.93377	0.000301595
SITE:FERT	5	23990.0	4798.00	3.85754	0.002934660
Residuals	110	136817.8	1243.80		

All Sites Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	24045.21	4809.042	79.39450	0.0000000
FERT	1	75.09	75.088	1.23966	0.2679637
SITE:FERT	5	921.26	184.252	3.04190	0.0130593
Residuals	110	6662.86	60.571		

2.7.3: FERTILISATION AT ALL SITES SUMMER 2002 and 2003

All Sites FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	237202.1	47440.4	38.72136	0.0000000
YEAR	1	53554.8	53554.8	43.71198	0.0000000
FERT	1	18220.8	18220.8	14.87198	0.0001511
SITE:YEAR	5	529951.6	105990.3	86.51040	0.0000000
SITE:FERT	5	61649.4	12329.9	10.06378	0.0000000
YEAR:FERT	1	2620.6	2620.6	2.13897	0.1450249
SITE:YEAR:FERT	5	13952.2	2790.4	2.27759	0.0479597
Residuals	220	269538.3	1225.2		

All Sites Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	17108.56	3421.713	84.3898	0.0000000
YEAR	1	8513.32	8513.322	209.9643	0.0000000
FERT	1	15.29	15.290	0.3771	0.5397926
SITE:YEAR	5	9823.10	1964.621	48.4535	0.0000000
SITE:FERT	5	1081.86	216.372	5.3364	0.0001191
YEAR:FERT	1	69.63	69.628	1.7172	0.1914141
SITE:YEAR:FERT	5	188.17	37.634	0.9282	0.4635030
Residuals	220	8920.24	40.547		

2.8.1: WT and SO HARVESTING AT ALL SITES SUMMER 2002

WT and SO plots FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	237494.5	47498.89	47.92157	0.0000000
FERT	1	2457.1	2457.14	2.47901	0.1200166
HARV	1	974.1	974.06	0.98272	0.3250415
SITE:FERT	5	55497.5	11099.51	11.19828	0.0000001
SITE:HARV	5	2857.4	571.48	0.57656	0.7177235
FERT:HARV	1	1562.9	1562.90	1.57680	0.2135193
SITE:FERT:HARV	5	3586.5	717.30	0.72368	0.6079852
Residuals	68	67400.2	991.18		

WT and SO plots Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2787.268	557.4536	26.23264	0.0000000
FERT	1	12.309	12.3087	0.57922	0.4492476
HARV	1	30.169	30.1688	1.41968	0.2375976
SITE:FERT	5	392.418	78.4837	3.69328	0.0051333
SITE:HARV	5	98.579	19.7157	0.92778	0.4685742
FERT:HARV	1	2.834	2.8337	0.13335	0.7161166
SITE:FERT:HARV	5	24.600	4.9200	0.23152	0.9474458
Residuals	68	1445.026	21.2504		

2.8.2: WT and SO HARVESTING AT ALL SITES SUMMER 2003

WT and SO plots FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	375842.0	75168.39	52.82372	0.0000000
FERT	1	17243.1	17243.05	12.11736	0.0008772
HARV	1	2714.4	2714.38	1.90750	0.1717631
SITE:FERT	5	24192.8	4838.56	3.40024	0.0084250
SITE:HARV	5	8856.8	1771.35	1.24480	0.2980615
FERT:HARV	1	2036.7	2036.73	1.43129	0.2357090
SITE:FERT:HARV	5	6856.2	1371.25	0.96363	0.4463334
Residuals	68	96764.3	1423.00		

WT and SO plots Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	22601.94	4520.388	129.2354	0.0000000
FERT	1	71.95	71.953	2.0571	0.1560817
HARV	1	490.63	490.631	14.0269	0.0003734
SITE:FERT	5	1293.64	258.727	7.3969	0.0000137
SITE:HARV	5	231.43	46.286	1.3233	0.2647710
FERT:HARV	1	51.31	51.310	1.4669	0.2300257
SITE:FERT:HARV	5	71.76	14.352	0.4103	0.8400236
Residuals	68	2378.50	34.978		

2.8.3: WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003

WT and SO plots FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	202995.9	40599.18	33.63387	0.0000000
YEAR	1	34773.2	34773.23	28.80744	0.0000003
FERT	1	16359.2	16359.21	13.55258	0.0003335
HARV	1	3470.2	3470.25	2.87488	0.0922598
SITE:YEAR	5	410340.5	82068.11	67.98827	0.0000000
SITE:FERT	5	64488.6	12897.73	10.68496	0.0000000
YEAR:FERT	1	3341.0	3340.98	2.76779	0.0984814
SITE:HARV	5	3453.5	690.69	0.57219	0.7211997
YEAR:HARV	1	218.2	218.19	0.18076	0.6713936
FERT:HARV	1	3584.0	3583.96	2.96909	0.0871424
SITE:YEAR:FERT	5	15201.7	3040.34	2.51873	0.0324602
SITE:YEAR:HARV	5	8260.7	1652.14	1.36869	0.2399168
SITE:FERT:HARV	5	5662.4	1132.48	0.93819	0.4584580
YEAR:FERT:HARV	1	15.7	15.66	0.01297	0.9094807
SITE:YEAR:FERT:HARV	5	4780.3	956.06	0.79204	0.5571580
Residuals	136	164164.5	1207.09		

WT and SO plots Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	16427.97	3285.593	116.8661	0.0000000
YEAR	1	6111.76	6111.761	217.3908	0.0000000
FERT	1	12.37	12.371	0.4400	0.5082327
HARV	1	382.06	382.062	13.5897	0.0003276
SITE:YEAR	5	8961.24	1792.249	63.7489	0.0000000
SITE:FERT	5	1434.64	286.928	10.2058	0.0000000
YEAR:FERT	1	71.89	71.891	2.5571	0.1121205
SITE:HARV	5	179.64	35.928	1.2779	0.2769889
YEAR:HARV	1	138.74	138.737	4.9348	0.0279747
FERT:HARV	1	15.01	15.014	0.5340	0.4661783
SITE:YEAR:FERT	5	251.42	50.283	1.7885	0.1192213
SITE:YEAR:HARV	5	150.37	30.073	1.0697	0.3799956
SITE:FERT:HARV	5	49.34	9.869	0.3510	0.8808684
YEAR:FERT:HARV	1	39.13	39.130	1.3918	0.2401577
SITE:YEAR:FERT:HARV	5	47.02	9.404	0.3345	0.8913520
Residuals	136	3823.53	28.114		

2.9.1: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002

WH/TARA/KIN/GD only FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	227048.6	75682.87	53.16889	0.0000000
FERT	1	1174.4	1174.42	0.82505	0.3670115
HARV	2	3169.5	1584.75	1.11332	0.3345557
SITE:FERT	3	18173.5	6057.83	4.25576	0.0082591
SITE:HARV	6	4778.1	796.34	0.55945	0.7609211
FERT:HARV	2	5503.3	2751.64	1.93309	0.1528054
SITE:FERT:HARV	6	7171.1	1195.19	0.83965	0.5438607
Residuals	66	93947.2	1423.44		

WH/TARA/KIN/GD only Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2151.743	717.2477	39.65732	0.0000000
FERT	1	3.852	3.8521	0.21299	0.6459543
HARV	2	386.681	193.3403	10.68997	0.0000951
SITE:FERT	3	245.165	81.7218	4.51848	0.0060742
SITE:HARV	6	234.963	39.1605	2.16522	0.0574535
FERT:HARV	2	2.665	1.3327	0.07369	0.9290392
SITE:FERT:HARV	6	71.013	11.8356	0.65440	0.6864289
Residuals	66	1193.685	18.0861		

2.9.2: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003

WH/TARA/KIN/GD only FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	413595.4	137865.1	226.1399	0.0000000
FERT	1	3424.5	3424.5	5.6171	0.0207168
HARV	2	2904.2	1452.1	2.3819	0.1002755
SITE:FERT	3	3186.9	1062.3	1.7425	0.1668536
SITE:HARV	6	3621.2	603.5	0.9900	0.4394020
FERT:HARV	2	13.6	6.8	0.0111	0.9889479
SITE:FERT:HARV	6	3617.8	603.0	0.9890	0.4400020
Residuals	66	40236.6	609.6		

WH/TARA/KIN/GD only Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	17130.18	5710.060	127.3734	0.0000000
FERT	1	179.62	179.621	4.0068	0.0494308
HARV	2	2061.03	1030.516	22.9876	0.0000000
SITE:FERT	3	785.48	261.828	5.8405	0.0013348
SITE:HARV	6	766.99	127.831	2.8515	0.0156966
FERT:HARV	2	68.56	34.280	0.7647	0.4695593
SITE:FERT:HARV	6	411.62	68.603	1.5303	0.1820704
Residuals	66	2958.73	44.829		

2.9.3: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003

WH/TARA/KIN/GD only FH Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	111984.0	37328.0	36.7205	0.0000000
YEAR	1	33637.1	33637.1	33.0897	0.0000001
FERT	1	294.0	294.0	0.2892	0.5916224
HARV	2	3380.7	1690.4	1.6628	0.1935455
SITE:YEAR	3	528660.0	176220.0	173.3521	0.0000000
SITE:FERT	3	9418.0	3139.3	3.0882	0.0294559
YEAR:FERT	1	4304.9	4304.9	4.2348	0.0415711
SITE:HARV	6	1471.2	245.2	0.2412	0.9620377
YEAR:HARV	2	2693.0	1346.5	1.3246	0.2694271
FERT:HARV	2	3006.6	1503.3	1.4788	0.2316566
SITE:YEAR:FERT	3	11942.5	3980.8	3.9160	0.0102256
SITE:YEAR:HARV	6	6928.0	1154.7	1.1359	0.3450841
SITE:FERT:HARV	6	6371.7	1062.0	1.0447	0.3994665
YEAR:FERT:HARV	2	2510.3	1255.1	1.2347	0.2942583
SITE:YEAR:FERT:HARV	6	4417.2	736.2	0.7242	0.6308193
Residuals	132	134183.8	1016.5		

WH/TARA/KIN/GD only Soil Microbial Biomass

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	12094.78	4031.59	128.1592	0.0000000
YEAR	1	11137.70	11137.70	354.0531	0.0000000
FERT	1	118.04	118.04	3.7524	0.0548686
HARV	2	2084.25	1042.13	33.1279	0.0000000
SITE:YEAR	3	7187.14	2395.71	76.1566	0.0000000
SITE:FERT	3	859.16	286.39	9.1039	0.0000161
YEAR:FERT	1	65.43	65.43	2.0800	0.1516075
SITE:HARV	6	493.92	82.32	2.6169	0.0198187
YEAR:HARV	2	363.46	181.73	5.7769	0.0039346
FERT:HARV	2	47.24	23.62	0.7509	0.4739400
SITE:YEAR:FERT	3	171.48	57.16	1.8171	0.1471433
SITE:YEAR:HARV	6	508.03	84.67	2.6916	0.0169460
SITE:FERT:HARV	6	378.96	63.16	2.0078	0.0689898
YEAR:FERT:HARV	2	23.98	11.99	0.3812	0.6838055
SITE:YEAR:FERT:HARV	6	103.68	17.28	0.5493	0.7697970
Residuals	132	4152.42	31.46		

2.10: NITROGEN MINERLISATION IN SOIL SAMPLES

Woodhill Winter 2003

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1115.28	1115.278	4.19022	0.0632053
HARV	2	10840.74	5420.372	20.36491	0.0001389
FERT:HARV	2	72.34	36.170	0.13589	0.8742597
Residuals	12	3193.95	266.162		

Berwick Winter 2003

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1689.74	1689.739	1.354601	0.2670947
HARV	1	6600.94	6600.937	5.291725	0.0401703
FERT:HARV	1	1218.76	1218.763	0.977037	0.3424437
Residuals	12	14968.89	1247.408		

Golden Downs Winter 2003

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	11044.3	11044.3	0.332709	0.5712123
HARV	2	207766.2	103883.1	3.129456	0.0681727
FERT:HARV	2	179970.9	89985.5	2.710794	0.0935202
Residuals	18	597514.5	33195.2		

STATISTICAL APPENDIX THREE: ANOVA Statistics of FH Litter and Soil Microbial PCA Distribution on Principal Axis

3.1.1: ALL SITES COMBINED ALL SUBSTRATES

```
Utilisation by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value        Pr(F)
     SITE   5  6.420022 1.284004 19.41923 5.218048e-014
Residuals 116  7.669949 0.066120
Utilisation by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq F Value Pr(F)
     SITE   5  10.68165 2.136331 38.0292     0
Residuals 116   6.51642 0.056176
Utilisation by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  9.091606 1.818321 48.13444     0
Residuals 116  4.382003 0.037776
Utilisation by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  9.570950 1.914190 40.44872     0
Residuals 116  5.489569 0.047324
Utilisation by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  19.65479 3.930959 148.3311     0
Residuals 116   3.07414 0.026501
Utilisation by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  19.16612 3.833225 130.5497     0
Residuals 116   3.40601 0.029362
Utilisation by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  18.91108 3.782217 208.0612     0
Residuals 116   2.10869 0.018178
Utilisation by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq F Value Pr(F)
     SITE   5  12.03348 2.406696 81.0309     0
Residuals 116   3.44531 0.029701
```

3.1.2: ALL SITES COMBINED AMINO ACIDS

```
Utilisation of AA by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     SITE   5  1.128656 0.2257312 19.39023 5.417888e-014
Residuals 116  1.350413 0.0116415
Utilisation of AA by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  1.554089 0.3108177 31.40677     0
Residuals 116  1.147996 0.0098965
Utilisation of AA by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     SITE   5  0.700585 0.1401170 9.448171 1.409032e-007
Residuals 116  1.720288 0.0148301
Utilisation of AA by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  1.383995 0.2767991 29.24979     0
Residuals 116  1.097741 0.0094633
Utilisation of AA by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.618627 0.7237254 166.8124     0
Residuals 116  0.503273 0.0043386
Utilisation of AA by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.670673 0.7341347 125.7211     0
Residuals 116  0.677369 0.0058394
Utilisation of AA by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.081568 0.6163135 94.96251     0
Residuals 116  0.752848 0.0064901
Utilisation of AA by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  2.762212 0.5524423 73.75516     0
Residuals 116  0.868865 0.0074902
```

3.1.3: ALL SITES COMBINED CARBOXYLIC ACIDS

```
Utilisation of CARB by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value        Pr(F)
     SITE   5  1.478827 0.2957654 17.68637 5.37792e-013
Residuals 116  1.939843 0.0167228
Utilisation of CARB by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     SITE   5  1.959287 0.3918574 22.36749 1.221245e-015
Residuals 116  2.032211 0.0175191
Utilisation of CARB by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     SITE   5  1.450690 0.2901380 18.07648 3.156364e-013
Residuals 116  1.861868 0.0160506
Utilisation of CARB by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     SITE   5  1.654039 0.3308078 24.09597 1.110223e-016
Residuals 116  1.592536 0.0137288
```

ALL SITES COMBINED CARBOXYLIC ACIDS continued

```
Utilisation of CARB by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.971569 0.9943139 98.79876     0
Residuals 116  1.167428 0.0100640
Utilisation of CARB by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.941862 0.9883724 110.3768     0
Residuals 116  1.038726 0.0089545
Utilisation of CARB by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.672609 0.9345218 150.6213     0
Residuals 116  0.719716 0.0062044
Utilisation of CARB by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.199513 0.6399026 76.17572     0
Residuals 116  0.974440 0.0084003
```

3.1.4: ALL SITES COMBINED CARBOHYDRATES

```
Utilisation of CHO by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value        Pr(F)
     SITE   5  2.287399 0.4574798 17.73866 5.005996e-013
Residuals 116  2.991639 0.0257900
Utilisation of CHO by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.989914 0.7979827 34.46996     0
Residuals 116  2.685410 0.0231501
Utilisation of CHO by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.325676 0.8651352 73.37406     0
Residuals 116  1.367727 0.0117907
Utilisation of CHO by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.987401 0.7974802 47.81206     0
Residuals 116  1.934820 0.0166795
Utilisation of CHO by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  5.557816 1.111563 108.0744     0
Residuals 116  1.193079 0.010285
Utilisation of CHO by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  5.922421 1.184484 113.6618     0
Residuals 116  1.208851 0.010421
Utilisation of CHO by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  6.131866 1.226373 216.9744     0
Residuals 116  0.655650 0.005652
Utilisation of CHO by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.467533 0.6935066 52.84606     0
Residuals 116  1.522285 0.0131231
```

3.1.5: ALL SITES COMBINED NITROGEN AND PHOSPHOROUS SOURCES

```
Utilisation of NP by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value        Pr(F)
     SITE   5  1.707729 0.3415459 16.47808 2.888911e-012
Residuals 116  2.404364 0.0207273
Utilisation of NP by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  3.319358 0.6638716 39.31032     0
Residuals 116  1.959005 0.0168880
Utilisation of NP by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  2.808553 0.5617105 53.39063     0
Residuals 116  1.220409 0.0105208
Utilisation of NP by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  2.681323 0.5362647 27.07645     0
Residuals 116  2.297447 0.0198056
Utilisation of NP by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     SITE   5  5.430475 1.086095 171.0971     0
Residuals 116  0.736348 0.006348
Utilisation of NP by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.506795 0.9013590 115.3775     0
Residuals 116  0.906222 0.0078123
Utilisation of NP by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  4.551591 0.9103182 129.9456     0
Residuals 116  0.812624 0.0070054
Utilisation of NP by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     SITE   5  2.660984 0.5321967 48.00406     0
Residuals 116  1.286033 0.0110865
```

3.2.1: WOODHILL ALL SUBSTRATES

Woodhill Utilisation by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.27042	1.270418	1.253538	0.2847875
HARV	2	1.06826	0.534129	0.527032	0.6034107
FERT:HARV	2	0.41493	0.207467	0.204711	0.8176705
Residuals	12	12.16159	1.013466		

Woodhill Utilisation by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.82087	1.820868	1.709773	0.2155125
HARV	2	0.05592	0.027962	0.026256	0.9741419
FERT:HARV	2	0.91190	0.455950	0.428132	0.6613006
Residuals	12	12.77972	1.064977		

Woodhill Utilisation by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.512072	0.5120720	0.962532	0.3459164
HARV	2	1.146154	0.5730772	1.077202	0.3713110
FERT:HARV	2	0.273261	0.1366305	0.256822	0.7776511
Residuals	12	6.384061	0.5320051		

Woodhill Utilisation by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.039481	0.039481	0.158346	0.6976723
HARV	2	0.941931	0.470965	1.888918	0.1935543
FERT:HARV	2	3.247657	1.623828	6.512749	0.0121560
Residuals	12	2.991969	0.249331		

Woodhill Utilisation by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.020740	0.020740	0.08557	0.7748806
HARV	2	1.775831	0.887915	3.66346	0.0572944
FERT:HARV	2	8.934865	4.467432	18.43222	0.0002193
Residuals	12	2.908449	0.242371		

Woodhill Utilisation by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.190962	0.190962	0.384322	0.5468910
HARV	2	4.529470	2.264735	4.557912	0.0336852
FERT:HARV	2	1.388266	0.694133	1.396984	0.2848259
Residuals	12	5.962559	0.496880		

Woodhill Utilisation by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.086806	0.086806	0.152289	0.7031956
HARV	2	2.393953	1.196977	2.099946	0.1652018
FERT:HARV	2	0.507807	0.253904	0.445442	0.6507155
Residuals	12	6.840043	0.570004		

Woodhill Utilisation by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.348891	0.348891	0.885341	0.3652991
HARV	2	6.241830	3.120915	7.919598	0.0064143
FERT:HARV	2	0.058135	0.029068	0.073762	0.9293107
Residuals	12	4.728899	0.394075		

3.2.2: WOODHILL AMINO ACIDS

Woodhill Utilisation of AA by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.079468	0.0794676	0.4607907	0.5101348
HARV	2	0.283014	0.1415072	0.8205259	0.4634473
FERT:HARV	2	0.011719	0.0058594	0.0339755	0.9666878
Residuals	12	2.069509	0.1724591		

Woodhill Utilisation of AA by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.544272	0.5442722	3.510604	0.0855273
HARV	2	0.041830	0.0209151	0.134904	0.8751064
FERT:HARV	2	0.268820	0.1344101	0.866957	0.4449606
Residuals	12	1.860439	0.1550366		

Woodhill Utilisation of AA by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.036630	0.0366302	0.1919243	0.6691020
HARV	2	0.033344	0.0166721	0.0873533	0.9169305
FERT:HARV	2	0.013863	0.0069317	0.0363188	0.9644384
Residuals	12	2.290292	0.1908577		

Woodhill Utilisation of AA by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000018	0.0000180	0.00042	0.9840106
HARV	2	0.207772	0.1038862	2.41662	0.1312449
FERT:HARV	2	1.055296	0.5276482	12.27423	0.0012528
Residuals	12	0.515859	0.0429883		

Woodhill Utilisation of AA by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000313	0.0003125	0.00613	0.9388874
HARV	2	0.674341	0.3371707	6.61329	0.0115861
FERT:HARV	2	1.839619	0.9198095	18.04120	0.0002416
Residuals	12	0.611806	0.0509838		

Woodhill Utilisation of AA by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000001	0.0000014	0.000014	0.9970497
HARV	2	0.930901	0.4654507	4.776624	0.0297859
FERT:HARV	2	0.328397	0.1641984	1.685063	0.2264763
Residuals	12	1.169321	0.0974434		

WOODHILL AMINO ACIDS continued

Woodhill Utilisation of AA by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.158860	0.1588601	1.201459	0.2945408
HARV	2	0.126029	0.0630144	0.476578	0.6321700
FERT:HARV	2	0.371071	0.1855354	1.403205	0.2833929
Residuals	12	1.586671	0.1322226		

Woodhill Utilisation of AA by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.419833	0.4198334	3.182718	0.0997067
HARV	2	0.710769	0.3553844	2.694136	0.1080311
FERT:HARV	2	0.036187	0.0180934	0.137164	0.8731744
Residuals	12	1.582924	0.1319103		

3.2.3: WOODHILL CARBOXYLIC ACIDS

Woodhill Utilisation of CARB by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.681334	0.6813336	3.112311	0.1031186
HARV	2	0.094220	0.0471102	0.215198	0.8094271
FERT:HARV	2	0.100601	0.0503004	0.229771	0.7981328
Residuals	12	2.626987	0.2189156		

Woodhill Utilisation of CARB by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.403501	0.4035014	1.533697	0.2392384
HARV	2	0.073841	0.0369207	0.140335	0.8704730
FERT:HARV	2	0.306857	0.1534287	0.583178	0.5731838
Residuals	12	3.157089	0.2630907		

Woodhill Utilisation of CARB by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.576380	0.5763801	5.057567	0.0440842
HARV	2	0.161291	0.0806457	0.707643	0.5122571
FERT:HARV	2	0.977599	0.4887994	4.289073	0.0393233
Residuals	12	1.367567	0.1139639		

Woodhill Utilisation of CARB by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.004769	0.0047694	0.043909	0.8375392
HARV	2	0.097644	0.0488221	0.449472	0.6482801
FERT:HARV	2	0.888025	0.4440127	4.087724	0.0442739
Residuals	12	1.303452	0.1086210		

Woodhill Utilisation of CARB by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.113129	0.1131294	0.894943	0.3628017
HARV	2	0.899235	0.4496176	3.556830	0.0612385
FERT:HARV	2	1.750459	0.8752296	6.923758	0.0100132
Residuals	12	1.516915	0.1264096		

Woodhill Utilisation of CARB by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.012482	0.0124820	0.088069	0.7717200
HARV	2	1.654437	0.8272185	5.836614	0.0169646
FERT:HARV	2	0.155071	0.0775355	0.547068	0.5924154
Residuals	12	1.700750	0.1417292		

Woodhill Utilisation of CARB by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.018304	0.0183042	0.141329	0.7135249
HARV	2	0.811087	0.4055434	3.131255	0.0804868
FERT:HARV	2	0.658051	0.3290254	2.540449	0.1202329
Residuals	12	1.554176	0.1295147		

Woodhill Utilisation of CARB by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.006347	0.006347	0.050963	0.8251948
HARV	2	2.011981	1.005991	8.077731	0.0059939
FERT:HARV	2	0.007330	0.003665	0.029429	0.9710696
Residuals	12	1.494465	0.124539		

3.2.4: WOODHILL CARBOHYDRATES

Woodhill Utilisation of CHO by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.533889	0.5338889	1.458999	0.2503565
HARV	2	0.383478	0.1917389	0.523980	0.6051067
FERT:HARV	2	0.308300	0.1541502	0.421258	0.6655593
Residuals	12	4.391139	0.3659282		

Woodhill Utilisation of CHO by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.514098	0.5140980	1.430619	0.2547628
HARV	2	0.228482	0.1142412	0.317907	0.7336146
FERT:HARV	2	0.193790	0.0968952	0.269637	0.7681623
Residuals	12	4.312243	0.3593536		

Woodhill Utilisation of CHO by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.411325	0.4113245	1.974269	0.1853511
HARV	2	0.449369	0.2246847	1.078438	0.3709222
FERT:HARV	2	0.370974	0.1854872	0.890298	0.4359928
Residuals	12	2.500113	0.2083427		

Woodhill Utilisation of CHO by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.088901	0.0889014	0.698605	0.4195847
HARV	2	0.151815	0.0759077	0.596498	0.5662745
FERT:HARV	2	0.868264	0.4341321	3.411495	0.0671361
Residuals	12	1.527068	0.1272557		

WOODHILL CARBOHYDRATES continued

Woodhill Utilisation of CHO by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.041664	0.041664	0.34426	0.5682561
HARV	2	0.212699	0.106349	0.87873	0.4404110
FERT:HARV	2	2.423107	1.211553	10.01066	0.0027698
Residuals	12	1.452316	0.121026		

Woodhill Utilisation of CHO by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.132441	0.1324409	0.793493	0.3905565
HARV	2	1.749413	0.8747067	5.240629	0.0231294
FERT:HARV	2	0.352121	0.1760604	1.054830	0.3784322
Residuals	12	2.002905	0.1669087		

Woodhill Utilisation of CHO by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000356	0.0003556	0.001420	0.9705571
HARV	2	0.862775	0.4313874	1.723206	0.2198476
FERT:HARV	2	0.022278	0.0111391	0.044496	0.9566367
Residuals	12	3.004079	0.2503399		

Woodhill Utilisation of CHO by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.040803	0.040803	0.275985	0.6089153
HARV	2	2.205720	1.102860	7.459614	0.0078471
FERT:HARV	2	0.003041	0.001520	0.010284	0.9897777
Residuals	12	1.774129	0.147844		

3.2.5: WOODHILL NITROGEN AND PHOSPHOROUS SOURCES

Woodhill Utilisation of NP by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.286020	0.2860201	0.9105632	0.3587928
HARV	2	0.431695	0.2158477	0.6871651	0.5217413
FERT:HARV	2	0.120831	0.0604157	0.1923373	0.8275226
Residuals	12	3.769360	0.3141133		

Woodhill Utilisation of NP by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.443996	0.4439961	1.213106	0.2923197
HARV	2	0.012307	0.0061534	0.016813	0.9833511
FERT:HARV	2	0.183433	0.0917167	0.250593	0.7823127
Residuals	12	4.391993	0.3659994		

Woodhill Utilisation of NP by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.080802	0.0808020	0.502959	0.4917524
HARV	2	0.761732	0.3808662	2.370736	0.1356206
FERT:HARV	2	0.018370	0.0091852	0.057174	0.9446855
Residuals	12	1.927837	0.1606531		

Woodhill Utilisation of NP by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.017174	0.0171742	0.119122	0.7359630
HARV	2	0.331021	0.1655104	1.147995	0.3497857
FERT:HARV	2	0.519307	0.2596537	1.800982	0.2070198
Residuals	12	1.730081	0.1441734		

Woodhill Utilisation of NP by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.048050	0.048050	0.79400	0.3904095
HARV	2	0.401305	0.200653	3.31568	0.0713871
FERT:HARV	2	3.106369	1.553185	25.66557	0.0000463
Residuals	12	0.726195	0.060516		

Woodhill Utilisation of NP by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.287282	0.2872820	1.460598	0.2501112
HARV	2	0.496372	0.2481862	1.261827	0.3181500
FERT:HARV	2	0.833583	0.4167915	2.119050	0.1628831
Residuals	12	2.360255	0.1966879		

Woodhill Utilisation of NP by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.005904	0.0059042	0.028721	0.8682486
HARV	2	0.686745	0.3433724	1.670319	0.2291009
FERT:HARV	2	0.103422	0.0517111	0.251546	0.7815970
Residuals	12	2.466875	0.2055729		

Woodhill Utilisation of NP by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.220891	0.2208909	1.934445	0.1895256
HARV	2	1.458543	0.7292715	6.386571	0.0129182
FERT:HARV	2	0.049945	0.0249724	0.218695	0.8066999
Residuals	12	1.370259	0.1141883		

3.3.1: TARAWERA ALL SUBSTRATES

```
Tarawera Utilisation by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1   0.01179 0.0117927 0.020103 0.8888249
     HARV  2   1.15861 0.5793065 0.987541 0.3917918
FERT:HARV  2   1.28427 0.6421372 1.094648 0.3559278
Residuals 18  10.55907 0.5866151
Tarawera Utilisation by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.785178 0.7851784 1.694547 0.2094167
     HARV  2  1.794042 0.8970212 1.935923 0.1731744
FERT:HARV  2  0.315676 0.1578380 0.340641 0.7158013
Residuals 18  8.340406 0.4633559
Tarawera Utilisation by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.391535 1.391535 2.903242 0.1056033
     HARV  2  0.265406 0.132703 0.276866 0.7613269
FERT:HARV  2  0.118438 0.059219 0.123552 0.8845185
Residuals 18  8.627470 0.479304
Tarawera Utilisation by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.452384 1.452384 4.267696 0.0535462
     HARV  2  0.554481 0.277241 0.814646 0.4584699
FERT:HARV  2  0.248505 0.124253 0.365105 0.6991475
Residuals 18  6.125768 0.340320
Tarawera Utilisation by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  0.037367 0.037367 0.138878 0.7137504
     HARV  2  0.700301 0.350150 1.301370 0.2965703
FERT:HARV  2  2.119752 1.059876 3.939138 0.0381096
Residuals 18  4.843131 0.269063
Tarawera Utilisation by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.024130 0.0241300 0.068545 0.7964403
     HARV  2  0.271384 0.1356920 0.385451 0.6856245
FERT:HARV  2  1.496393 0.7481963 2.125349 0.1483747
Residuals 18  6.336622 0.3520346
Tarawera Utilisation by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  0.018704 0.018704  0.13898 0.7136543
     HARV  2  1.763293 0.881646  6.55084 0.0072845
FERT:HARV  2  5.511790 2.755895 20.47695 0.0000231
Residuals 18  2.422534 0.134585
Tarawera Utilisation by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
     FERT  1  1.216801 1.216801 7.509147 0.01344818
     HARV  2  1.593451 0.796725 4.916769 0.01978504
FERT:HARV  2  1.304956 0.652478 4.026587 0.03586798
Residuals 18  2.916764 0.162042
```

3.3.2: TARAWERA AMINO ACIDS

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Tarawera Utilisation of AA by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.000840 0.0008402 0.008665 0.9268655
     HARV  2  0.595965 0.2979825 3.073052 0.0710933
FERT:HARV  2  0.034669 0.0173345 0.178769 0.8377660
Residuals 18  1.745394 0.0969663
Tarawera Utilisation of AA by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.306230 0.3062300 3.937420 0.0626834
     HARV  2  0.376707 0.1883535 2.421796 0.1171043
FERT:HARV  2  0.065326 0.0326632 0.419974 0.6633387
Residuals 18  1.399937 0.0777743
Tarawera Utilisation of AA by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.183225 0.1832254 1.401813 0.2518203
     HARV  2  0.035074 0.0175368 0.134170 0.8753080
FERT:HARV  2  0.024482 0.0122409 0.093652 0.9110404
Residuals 18  2.352708 0.1307060
Tarawera Utilisation of AA by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq    Mean Sq   F Value     Pr(F)
     FERT  1  0.014017 0.01401667 0.1659913 0.6885039
     HARV  2  0.049780 0.02488987 0.2947564 0.7482393
FERT:HARV  2  0.097708 0.04885404 0.5785501 0.5708008
Residuals 18  1.519960 0.08444219
Tarawera Utilisation of AA by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.010292 0.0102920 0.173913 0.6815884
     HARV  2  0.494069 0.2470345 4.174353 0.0324055
FERT:HARV  2  0.561682 0.2808408 4.745606 0.0221161
Residuals 18  1.065224 0.0591791
Tarawera Utilisation of AA by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.032340 0.0323400 0.3154948 0.5812549
     HARV  2  0.061233 0.0306165 0.2986811 0.7454017
FERT:HARV  2  0.007104 0.0035518 0.0346497 0.9660080
Residuals 18  1.845104 0.1025058
```

TARAWERA AMINO ACIDS continued

Tarawera Utilisation of AA by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001080	0.0010800	0.08281	0.7768146
HARV	2	0.556452	0.2782258	21.33186	0.0000178
FERT:HARV	2	1.078886	0.5394430	41.35965	0.0000002
Residuals	18	0.234769	0.0130427		

Tarawera Utilisation of AA by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0803884	0.0803884	1.608400	0.2208754
HARV	2	0.2277363	0.1138682	2.278259	0.1312212
FERT:HARV	2	0.6199680	0.3099840	6.202118	0.0089340
Residuals	18	0.8996462	0.0499803		

3.3.3: TARAWERA CARBOXYLIC ACIDS

Tarawera Utilisation of CARB by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.022387	0.0223870	0.156935	0.6966513
HARV	2	0.409129	0.2045647	1.434011	0.2643144
FERT:HARV	2	0.133625	0.0668127	0.468361	0.6334456
Residuals	18	2.567737	0.1426521		

Tarawera Utilisation of CARB by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.119709	0.1197094	0.845428	0.3700072
HARV	2	0.307810	0.1539052	1.086931	0.3583862
FERT:HARV	2	0.000763	0.0003815	0.002694	0.9973097
Residuals	18	2.548730	0.1415961		

Tarawera Utilisation of CARB by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.669670	0.6696700	5.121017	0.0362380
HARV	2	0.046624	0.0233122	0.178270	0.8381759
FERT:HARV	2	0.114725	0.0573627	0.438657	0.6516148
Residuals	18	2.353841	0.1307690		

Tarawera Utilisation of CARB by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.350900	0.3509002	3.118685	0.0943547
HARV	2	0.029973	0.0149865	0.133195	0.8761490
FERT:HARV	2	0.132969	0.0664847	0.590894	0.5642231
Residuals	18	2.025278	0.1125154		

Tarawera Utilisation of CARB by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.005133	0.0051334	0.058482	0.8116451
HARV	2	0.468628	0.2343138	2.669423	0.0965468
FERT:HARV	2	0.569273	0.2846366	3.242727	0.0627017
Residuals	18	1.579985	0.0877769		

Tarawera Utilisation of CARB by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.055970	0.05597004	0.5633157	0.4626266
HARV	2	0.061810	0.03090504	0.3110467	0.7365395
FERT:HARV	2	0.187045	0.09352254	0.9412664	0.4085142
Residuals	18	1.788448	0.09935821		

Tarawera Utilisation of CARB by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000001	0.000001	0.00003	0.9960272
HARV	2	0.466996	0.233498	8.92790	0.0020250
FERT:HARV	2	2.051601	1.025800	39.22196	0.0000003
Residuals	18	0.470767	0.026154		

Tarawera Utilisation of CARB by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000045	0.0000454	0.00148	0.9697650
HARV	2	0.516707	0.2583533	8.41049	0.0026356
FERT:HARV	2	1.263249	0.6316246	20.56205	0.0000225
Residuals	18	0.552924	0.0307180		

3.3.4: TARAWERA CARBOHYDRATES

Tarawera Utilisation of CHO by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.011267	0.0112667	0.047819	0.8293629
HARV	2	0.213364	0.1066820	0.452790	0.6428984
FERT:HARV	2	0.664579	0.3322893	1.410335	0.2697742
Residuals	18	4.240984	0.2356102		

Tarawera Utilisation of CHO by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.097028	0.0970282	0.523970	0.4784560
HARV	2	0.720432	0.3602158	1.945231	0.1718534
FERT:HARV	2	0.720210	0.3601050	1.944633	0.1719379
Residuals	18	3.333220	0.1851789		

Tarawera Utilisation of CHO by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.288643	0.2886427	2.308509	0.1460375
HARV	2	0.120027	0.0600133	0.479975	0.6264954
FERT:HARV	2	0.026099	0.0130493	0.104366	0.9014369
Residuals	18	2.250616	0.1250342		

Tarawera Utilisation of CHO by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.662008	0.6620082	7.015682	0.0163332
HARV	2	0.523959	0.2619796	2.776349	0.0889378
FERT:HARV	2	0.176819	0.0884095	0.936927	0.4101226
Residuals	18	1.698502	0.0943612		

TARAWERA CARBOHYDRATES continued

Tarawera Utilisation of CHO by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001536	0.0015360	0.010324	0.9201923
HARV	2	0.200986	0.1004930	0.675442	0.5213692
FERT:HARV	2	0.480256	0.2401279	1.613966	0.2266122
Residuals	18	2.678062	0.1487812		

Tarawera Utilisation of CHO by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.100621	0.1006215	0.633621	0.4364031
HARV	2	0.124173	0.0620865	0.390963	0.6820111
FERT:HARV	2	0.747309	0.3736545	2.352928	0.1236550
Residuals	18	2.858472	0.1588040		

Tarawera Utilisation of CHO by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.004565	0.0045650	0.040728	0.8423274
HARV	2	0.519260	0.2596302	2.316336	0.1273005
FERT:HARV	2	0.653397	0.3266987	2.914699	0.0800635
Residuals	18	2.017558	0.1120866		

Tarawera Utilisation of CHO by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.643210	0.6432100	5.561728	0.0298686
HARV	2	0.432197	0.2160983	1.868565	0.1830765
FERT:HARV	2	0.176183	0.0880913	0.761710	0.4813371
Residuals	18	2.081688	0.1156493		

3.3.5: TARAWERA NITROGEN AND PHOSPHOROUS SOURCES

Tarawera Utilisation of NP by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000204	0.0002042	0.001177	0.9730127
HARV	2	0.321336	0.1606682	0.926023	0.4141951
FERT:HARV	2	0.717082	0.3585412	2.066479	0.1556314
Residuals	18	3.123061	0.1735034		

Tarawera Utilisation of NP by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.324338	0.3243375	1.808141	0.1954321
HARV	2	0.383899	0.1919495	1.070094	0.3638151
FERT:HARV	2	0.116179	0.0580895	0.323842	0.7274926
Residuals	18	3.228772	0.1793762		

Tarawera Utilisation of NP by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.408726	0.4087260	2.540227	0.1283868
HARV	2	0.130908	0.0654538	0.406795	0.6717500
FERT:HARV	2	0.007358	0.0036789	0.022864	0.9774236
Residuals	18	2.896224	0.1609014		

Tarawera Utilisation of NP by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.432017	0.4320167	2.680819	0.1189265
HARV	2	0.133975	0.0669874	0.415681	0.6660657
FERT:HARV	2	0.036153	0.0180763	0.112170	0.8945123
Residuals	18	2.900718	0.1611510		

Tarawera Utilisation of NP by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.002282	0.0022815	0.032793	0.8583209
HARV	2	0.496004	0.2480021	3.564680	0.0496386
FERT:HARV	2	0.896459	0.4482296	6.442668	0.0077568
Residuals	18	1.252297	0.0695721		

Tarawera Utilisation of NP by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.035497	0.0354970	0.292083	0.5955134
HARV	2	0.187873	0.0939365	0.772945	0.4763798
FERT:HARV	2	0.492854	0.2464272	2.027697	0.1606272
Residuals	18	2.187550	0.1215306		

Tarawera Utilisation of NP by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.111793	0.1117935	1.804855	0.1958198
HARV	2	0.871186	0.4355930	7.032453	0.0055358
FERT:HARV	2	1.193321	0.5966604	9.632812	0.0014311
Residuals	18	1.114927	0.0619404		

Tarawera Utilisation of NP by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.580326	0.5803260	7.663225	0.0126688
HARV	2	0.735550	0.3677749	4.856480	0.0205734
FERT:HARV	2	0.210248	0.1051239	1.388164	0.2750004
Residuals	18	1.363117	0.0757287		

3.4.1: BERWICK ALL SUBSTRATES

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Berwick Utilisation by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   2.79893 2.798929 3.349192 0.0921750
     HARV  1   0.41474 0.414736 0.496272 0.4945880
FERT:HARV  1   0.17264 0.172640 0.206581 0.6575727
Residuals 12  10.02843 0.835703
Berwick Utilisation by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   6.07253 6.072528 7.078214 0.0207726
     HARV  1   0.04111 0.041108 0.047915 0.8304098
FERT:HARV  1   1.06451 1.064508 1.240804 0.2871304
Residuals 12  10.29502 0.857918
Berwick Utilisation by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  2.641438 2.641438 3.586940 0.0825879
     HARV  1  0.012377 0.012377 0.016807 0.8989983
FERT:HARV  1  0.799683 0.799683 1.085930 0.3179150
Residuals 12  8.836850 0.736404
Berwick Utilisation by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.129438 1.129438 1.784765 0.2063490
     HARV  1  0.136715 0.136715 0.216041 0.6503942
FERT:HARV  1  1.321925 1.321925 2.088938 0.1739738
Residuals 12  7.593857 0.632821
Berwick Utilisation by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   0.50873 0.508726 0.544723 0.4746687
     HARV  1   2.25075 2.250750 2.410013 0.1465248
FERT:HARV  1   0.16423 0.164228 0.175848 0.6823749
Residuals 12  11.20699 0.933916
Berwick Utilisation by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   0.33437 0.334373 0.394302 0.5418126
     HARV  1   4.67965 4.679651 5.518373 0.0367713
FERT:HARV  1   0.36271 0.362705 0.427712 0.5254491
Residuals 12  10.17615 0.848013
Berwick Utilisation by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1   0.08367 0.0836656 0.0928708 0.7657795
     HARV  1   0.01398 0.0139831 0.0155215 0.9029144
FERT:HARV  1   0.15347 0.1534681 0.1703532 0.6870769
Residuals 12  10.81058 0.9008817
Berwick Utilisation by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1   0.00179 0.0017851 0.0019564 0.9654476
     HARV  1   0.46957 0.4695676 0.5146382 0.4868683
FERT:HARV  1   0.15074 0.1507381 0.1652064 0.6915629
Residuals 12  10.94907 0.9124226
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3.4.2: BERWICK AMINO ACIDS

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Berwick Utilisation of AA by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.144590 0.1445901 0.834597 0.3789364
     HARV  1  0.010558 0.0105576 0.060940 0.8091891
FERT:HARV  1  0.461381 0.4613806 2.663162 0.1286433
Residuals 12  2.078945 0.1732454
Berwick Utilisation of AA by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.710228 0.7102276 4.692740 0.0511346
     HARV  1  0.036005 0.0360051 0.237899 0.6345174
FERT:HARV  1  0.565880 0.5658801 3.738982 0.0770916
Residuals 12  1.816152 0.1513460
Berwick Utilisation of AA by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.713603 0.7136026 4.838793 0.0481605
     HARV  1  0.112058 0.1120576 0.759839 0.4004830
FERT:HARV  1  0.098439 0.0984391 0.667495 0.4298485
Residuals 12  1.769704 0.1474753
Berwick Utilisation of AA by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.081653 0.0816531 0.4688036 0.5065476
     HARV  1  0.147648 0.1476481 0.8477079 0.3753403
FERT:HARV  1  0.173681 0.1736806 0.9971712 0.3377069
Residuals 12  2.090079 0.1741733
Berwick Utilisation of AA by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.066952 0.0669516 0.440323 0.5195119
     HARV  1  0.859793 0.8597926 5.654626 0.0348931
FERT:HARV  1  0.020521 0.0205206 0.134958 0.7197427
Residuals 12  1.824614 0.1520512
Berwick Utilisation of AA by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.002678 0.0026781 0.016628 0.8995349
     HARV  1  0.782783 0.7827826 4.860148 0.0477433
FERT:HARV  1  0.000077 0.0000766 0.000475 0.9829636
Residuals 12  1.932738 0.1610615
```

BERWICK AMINO ACIDS continued

Berwick Utilisation of AA by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.203176	0.2031756	2.089812	0.1738906
HARV	1	0.007098	0.0070981	0.073009	0.7915961
FERT:HARV	1	0.215064	0.2150641	2.212094	0.1627308
Residuals	12	1.166663	0.0972219		

Berwick Utilisation of AA by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.140063	0.1400631	0.856414	0.3729807
HARV	1	0.003813	0.0038131	0.023315	0.8811783
FERT:HARV	1	0.315002	0.3150016	1.926074	0.1904184
Residuals	12	1.962551	0.1635459		

3.4.3: BERWICK CARBOXYLIC ACIDS

Berwick Utilisation of CARB by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.961380	0.9613803	4.550206	0.0542523
HARV	1	0.031152	0.0311522	0.147443	0.7077078
FERT:HARV	1	0.102400	0.1024000	0.484658	0.4995822
Residuals	12	2.535394	0.2112828		

Berwick Utilisation of CARB by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.586340	1.586340	8.701786	0.0121470
HARV	1	0.002809	0.002809	0.015409	0.9032662
FERT:HARV	1	0.105950	0.105950	0.581185	0.4605713
Residuals	12	2.187606	0.182301		

Berwick Utilisation of CARB by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.708964	0.7089640	2.844441	0.1174915
HARV	1	0.006006	0.0060062	0.024098	0.8792171
FERT:HARV	1	0.628056	0.6280563	2.519830	0.1384080
Residuals	12	2.990946	0.2492455		

Berwick Utilisation of CARB by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.780572	0.7805723	4.798827	0.0489532
HARV	1	0.069169	0.0691690	0.425239	0.5266279
FERT:HARV	1	0.263169	0.2631690	1.617919	0.2274797
Residuals	12	1.951908	0.1626590		

Berwick Utilisation of CARB by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.083521	0.0835210	0.2633779	0.6171255
HARV	1	0.143641	0.1436410	0.4529623	0.5136844
FERT:HARV	1	0.000144	0.0001440	0.0004541	0.9833490
Residuals	12	3.805376	0.3171147		

Berwick Utilisation of CARB by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.078821	0.0788206	0.278519	0.6072940
HARV	1	0.608010	0.6080101	2.148457	0.1684206
FERT:HARV	1	0.019811	0.0198106	0.070002	0.7958229
Residuals	12	3.395982	0.2829985		

Berwick Utilisation of CARB by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000039	0.0000391	0.000138497	0.9908037
HARV	1	0.001278	0.0012781	0.004531393	0.9474390
FERT:HARV	1	0.000541	0.0005406	0.001916574	0.9658009
Residuals	12	3.384555	0.2820463		

Berwick Utilisation of CARB by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.004658	0.0046581	0.0173849	0.8972864
HARV	1	0.034689	0.0346891	0.1294673	0.7252378
FERT:HARV	1	0.004323	0.0043231	0.0161346	0.9010265
Residuals	12	3.215243	0.2679369		

3.4.4: BERWICK CARBOHYDRATES

Berwick Utilisation of CHO by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.758206	0.7582056	2.161532	0.1672311
HARV	1	0.260866	0.2608656	0.743689	0.4053864
FERT:HARV	1	0.006848	0.0068476	0.019521	0.8911997
Residuals	12	4.209268	0.3507724		

Berwick Utilisation of CHO by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.837380	1.837380	4.196202	0.0630425
HARV	1	0.034040	0.034040	0.077741	0.7851292
FERT:HARV	1	0.183612	0.183612	0.419333	0.5294643
Residuals	12	5.254409	0.437867		

Berwick Utilisation of CHO by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.088892	1.088892	3.337669	0.0926733
HARV	1	0.018906	0.018906	0.057951	0.8138274
FERT:HARV	1	0.113569	0.113569	0.348111	0.5661288
Residuals	12	3.914921	0.326243		

Berwick Utilisation of CHO by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.622521	0.6225210	2.442258	0.1440809
HARV	1	0.043890	0.0438902	0.172189	0.6854962
FERT:HARV	1	0.639200	0.6392003	2.507693	0.1392768
Residuals	12	3.058748	0.2548957		

BERWICK CARBOHYDRATES continued

Berwick Utilisation of CHO by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.147648	0.1476481	0.414996	0.5315654
HARV	1	0.735735	0.7357351	2.067938	0.1759889
FERT:HARV	1	0.160601	0.1606006	0.451402	0.5143974
Residuals	12	4.269383	0.3557819		

Berwick Utilisation of CHO by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.178929	0.178929	0.529741	0.4806769
HARV	1	2.115570	2.115570	6.263400	0.0277785
FERT:HARV	1	0.417962	0.417962	1.237428	0.2877561
Residuals	12	4.053205	0.337767		

Berwick Utilisation of CHO by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.008100	0.0081000	0.0217747	0.8851383
HARV	1	0.041820	0.0418203	0.1124228	0.7431913
FERT:HARV	1	0.017956	0.0179560	0.0482700	0.8297943
Residuals	12	4.463890	0.3719908		

Berwick Utilisation of CHO by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.119370	0.1193703	0.322570	0.5805393
HARV	1	0.393129	0.3931290	1.062337	0.3230098
FERT:HARV	1	0.001722	0.0017223	0.004654	0.9467341
Residuals	12	4.440727	0.3700605		

3.4.5: BERWICK NITROGEN AND PHOSPHOROUS SOURCES

Berwick Utilisation of NP by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.891608	0.8916081	3.875724	0.0725241
HARV	1	0.046981	0.0469806	0.204219	0.6593960
FERT:HARV	1	0.009653	0.0096531	0.041961	0.8411279
Residuals	12	2.760593	0.2300494		

Berwick Utilisation of NP by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.917533	1.917533	8.568651	0.0126691
HARV	1	0.124786	0.124786	0.557614	0.4696014
FERT:HARV	1	0.391563	0.391563	1.749732	0.2105650
Residuals	12	2.685416	0.223785		

Berwick Utilisation of NP by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.378840	0.3788403	2.007878	0.1819199
HARV	1	0.027722	0.0277222	0.146930	0.7081911
FERT:HARV	1	0.170156	0.1701563	0.901839	0.3610236
Residuals	12	2.264123	0.1886769		

Berwick Utilisation of NP by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.182970	0.1829701	0.8139952	0.3846935
HARV	1	0.006281	0.0062806	0.0279409	0.8700316
FERT:HARV	1	0.221135	0.2211351	0.9837832	0.3408459
Residuals	12	2.697363	0.2247803		

Berwick Utilisation of NP by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.165039	0.1650391	0.603130	0.4524233
HARV	1	0.653268	0.6532681	2.387346	0.1482741
FERT:HARV	1	0.035250	0.0352501	0.128820	0.7258941
Residuals	12	3.283653	0.2736378		

Berwick Utilisation of NP by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.125848	0.125848	0.481417	0.5009922
HARV	1	1.000500	1.000500	3.827312	0.0741026
FERT:HARV	1	0.085118	0.085118	0.325611	0.5787840
Residuals	12	3.136927	0.261411		

Berwick Utilisation of NP by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.224439	0.2244391	0.9571529	0.3472174
HARV	1	0.029498	0.0294981	0.1257988	0.7289835
FERT:HARV	1	0.120583	0.1205826	0.5142418	0.4870326
Residuals	12	2.813833	0.2344861		

Berwick Utilisation of NP by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.161202	0.1612023	0.6956452	0.4205441
HARV	1	0.087912	0.0879122	0.3793727	0.5494441
FERT:HARV	1	0.133225	0.1332250	0.5749134	0.4629450
Residuals	12	2.780766	0.2317305		

3.5.1: BURNHAM ALL SUBSTRATES

Burnham Utilisation by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.64200	0.642002	0.735622	0.4078710
HARV	1	1.93558	1.935577	2.217832	0.1622298
FERT:HARV	1	0.07250	0.072496	0.083067	0.7781006
Residuals	12	10.47280	0.872733		

Burnham Utilisation by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.297891	1.297891	2.316851	0.1538856
HARV	1	3.132015	3.132015	5.590928	0.0357565
FERT:HARV	1	0.163418	0.163418	0.291716	0.5990038
Residuals	12	6.722351	0.560196		

Burnham Utilisation by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.05990	0.0599026	0.0710801	0.7942967
HARV	1	0.23693	0.2369256	0.2811348	0.6056310
FERT:HARV	1	0.40800	0.4080016	0.4841328	0.4998105
Residuals	12	10.11297	0.8427473		

Burnham Utilisation by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.009264	0.0092641	0.0111269	0.9177343
HARV	1	0.000410	0.0004101	0.0004925	0.9826589
FERT:HARV	1	0.473000	0.4730001	0.5681137	0.4655422
Residuals	12	9.990959	0.8325799		

Burnham Utilisation by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	3.969060	3.969060	6.683521	0.0238658
HARV	1	0.079665	0.079665	0.134148	0.7205450
FERT:HARV	1	0.087173	0.087173	0.146790	0.7083224
Residuals	12	7.126292	0.593858		

Burnham Utilisation by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	4.498641	4.498641	8.378275	0.0134625
HARV	1	0.113569	0.113569	0.211511	0.6538069
FERT:HARV	1	0.018496	0.018496	0.034447	0.8558595
Residuals	12	6.443294	0.536941		

Burnham Utilisation by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.338724	0.338724	0.453655	0.5133683
HARV	1	1.638400	1.638400	2.194320	0.1642949
FERT:HARV	1	0.003844	0.003844	0.005148	0.9439816
Residuals	12	8.959858	0.746655		

Burnham Utilisation by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.083521	0.083521	0.316577	0.5840310
HARV	1	2.047761	2.047761	7.761798	0.0164662
FERT:HARV	1	0.779689	0.779689	2.955320	0.1112596
Residuals	12	3.165907	0.263826		

3.5.2: BURNHAM AMINO ACIDS

Burnham Utilisation of AA by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.778365	0.7783651	7.149339	0.0202670
HARV	1	0.297298	0.2972976	2.730699	0.1243407
FERT:HARV	1	0.094403	0.0944026	0.867094	0.3701166
Residuals	12	1.306468	0.1088723		

Burnham Utilisation of AA by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.592130	0.5921302	6.133123	0.0291436
HARV	1	0.178084	0.1780840	1.844545	0.1994060
FERT:HARV	1	0.241572	0.2415723	2.502139	0.1396767
Residuals	12	1.158556	0.0965463		

Burnham Utilisation of AA by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.172848	0.1728481	0.8360040	0.3785479
HARV	1	0.072496	0.0724956	0.3506350	0.5647445
FERT:HARV	1	0.135977	0.1359766	0.6576698	0.4331742
Residuals	12	2.481061	0.2067551		

Burnham Utilisation of AA by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.216225	0.2162250	1.864903	0.1971111
HARV	1	0.130682	0.1306822	1.127112	0.3092921
FERT:HARV	1	0.022650	0.0226503	0.195354	0.6663573
Residuals	12	1.391333	0.1159444		

Burnham Utilisation of AA by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.800130	0.8001303	8.562591	0.0126935
HARV	1	0.178929	0.1789290	1.914808	0.1916286
FERT:HARV	1	0.000600	0.0006003	0.006424	0.9374413
Residuals	12	1.121338	0.0934449		

Burnham Utilisation of AA by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.069282	2.069282	88.66278	0.0000007
HARV	1	0.026732	0.026732	1.14540	0.3055688
FERT:HARV	1	0.000256	0.000256	0.01097	0.9183184
Residuals	12	0.280065	0.023339		

BURNHAM AMINO ACIDS continued

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Burnham Utilisation of AA by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.480596 0.4805956 3.088758 0.1042919
     HARV  1  0.035816 0.0358156 0.230184 0.6400131
FERT:HARV  1  0.000315 0.0003151 0.002025 0.9648485
Residuals 12  1.867141 0.1555951
Burnham Utilisation of AA by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1 0.0278890 0.0278890  0.51416 0.4870646
     HARV  1 0.1440202 0.1440202  2.65517 0.1291644
FERT:HARV  1 0.9731823 0.9731823 17.94170 0.0011561
Residuals 12 0.6508965 0.0542414
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3.5.3: BURNHAM CARBOXYLIC ACIDS

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Burnham Utilisation of CARB by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.118853 0.1188526 0.578933 0.4614213
     HARV  1  0.527439 0.5274391 2.569164 0.1349457
FERT:HARV  1  0.049395 0.0493951 0.240604 0.6326167
Residuals 12  2.463552 0.2052960
Burnham Utilisation of CARB by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.099698 0.0996981 0.4718046 0.5052158
     HARV  1  0.100648 0.1006476 0.4762980 0.5032336
FERT:HARV  1  0.130863 0.1308631 0.6192878 0.4465762
Residuals 12  2.535746 0.2113122
Burnham Utilisation of CARB by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.078400 0.0784000 0.3715387 0.5535331
     HARV  1  0.077841 0.0778410 0.3688896 0.5549294
FERT:HARV  1  0.179352 0.1793522 0.8499528 0.3747297
Residuals 12  2.532172 0.2110144
Burnham Utilisation of CARB by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.019321 0.0193210 0.1084984 0.7475384
     HARV  1  0.012210 0.0122103 0.0685675 0.7978747
FERT:HARV  1  0.124962 0.1249623 0.7017340 0.4185739
Residuals 12  2.136916 0.1780764
Burnham Utilisation of CARB by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.101442 0.1014423 0.466159 0.5077267
     HARV  1  0.398792 0.3987922 1.832574 0.2007718
FERT:HARV  1  0.194481 0.1944810 0.893700 0.3631235
Residuals 12  2.611359 0.2176132
Burnham Utilisation of CARB by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.287090 1.287090 9.600294 0.0092168
     HARV  1  0.070490 0.070490 0.525781 0.4822871
FERT:HARV  1  0.014400 0.014400 0.107408 0.7487614
Residuals 12  1.608814 0.134068
Burnham Utilisation of CARB by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.033306 0.0333063 0.1826712 0.6766566
     HARV  1  0.064516 0.0645160 0.3538440 0.5629940
FERT:HARV  1  0.095790 0.0957903 0.5253705 0.4824544
Residuals 12  2.187948 0.1823290
Burnham Utilisation of CARB by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.057840 0.0578403 0.3234197 0.5800475
     HARV  1  0.041006 0.0410063 0.2292906 0.6406572
FERT:HARV  1  0.002704 0.0027040 0.0151197 0.9041725
Residuals 12  2.146076 0.1788396
```

3.5.4: BURNHAM CARBOHYDRATES

```
Burnham Utilisation of CHO by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.204983 0.2049826 0.529150 0.4809165
     HARV  1  0.713603 0.7136026 1.842122 0.1996815
FERT:HARV  1  0.017227 0.0172266 0.044469 0.8365214
Residuals 12  4.648569 0.3873808
Burnham Utilisation of CHO by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  0.354323 0.354323 1.766780 0.2084994
     HARV  1  1.883070 1.883070 9.389669 0.0098211
FERT:HARV  1  0.112728 0.112728 0.562103 0.4678588
Residuals 12  2.406564 0.200547
Burnham Utilisation of CHO by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq    F Value     Pr(F)
     FERT  1  0.025841 0.0258406 0.08091878 0.7809054
     HARV  1  0.012266 0.0122656 0.03840916 0.8479034
FERT:HARV  1  0.002475 0.0024751 0.00775057 0.9312991
Residuals 12  3.832074 0.3193395
Burnham Utilisation of CHO by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.015068 0.0150676 0.0428537 0.8394721
     HARV  1  0.000203 0.0002031 0.0005775 0.9812222
FERT:HARV  1  0.111723 0.1117231 0.3177520 0.5833427
Residuals 12  4.219255 0.3516046
```

BURNHAM CARBOHYDRATES contiuned

```
Burnham Utilisation of CHO by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.808201 0.8082010 2.637640 0.1303175
     HARV  1  0.074802 0.0748023 0.244124 0.6301634
FERT:HARV  1  0.019182 0.0191822 0.062603 0.8066602
Residuals 12  3.676928 0.3064107
Burnham Utilisation of CHO by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.672400 0.6724000 2.209647 0.1629450
     HARV  1  0.019044 0.0190440 0.062583 0.8066912
FERT:HARV  1  0.010506 0.0105062 0.034526 0.8556968
Residuals 12  3.651624 0.3043020
Burnham Utilisation of CHO by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.024103 0.0241026 0.089396 0.7700609
     HARV  1  0.794327 0.7943266 2.946152 0.1117591
FERT:HARV  1  0.061133 0.0611326 0.226740 0.6425038
Residuals 12  3.235379 0.2696149
Burnham Utilisation of CHO by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.205436 0.2054356 1.144549 0.3057406
     HARV  1  0.685170 0.6851701 3.817309 0.0744339
FERT:HARV  1  0.005513 0.0055131 0.030715 0.8638000
Residuals 12  2.153884 0.1794904
```

3.5.5: BURNHAM NITROGEN AND PHOSPHOROUS SOURCES

```
Burnham Utilisation of NP by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.064136 0.0641356 0.189467 0.6710862
     HARV  1  0.560627 0.5606266 1.656187 0.2223900
FERT:HARV  1  0.027806 0.0278056 0.082142 0.7793031
Residuals 12  4.062053 0.3385044
Burnham Utilisation of NP by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.491051 0.4910506 2.326690 0.1530865
     HARV  1  0.930743 0.9307426 4.410033 0.0575441
FERT:HARV  1  0.078260 0.0782601 0.370811 0.5539160
Residuals 12  2.532614 0.2110511
Burnham Utilisation of NP by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.000390 0.0003901 0.0014196 0.9705641
     HARV  1  0.014581 0.0145806 0.0530656 0.8216925
FERT:HARV  1  0.173681 0.1736806 0.6321063 0.4420257
Residuals 12  3.297178 0.2747648
Burnham Utilisation of NP by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.052556 0.0525556 0.1560614 0.6997410
     HARV  1  0.028985 0.0289851 0.0860698 0.7742462
FERT:HARV  1  0.169127 0.1691266 0.5022137 0.4920672
Residuals 12  4.041146 0.3367621
Burnham Utilisation of NP by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.538022 0.5380223 2.411657 0.1463989
     HARV  1  0.025760 0.0257602 0.115469 0.7398753
FERT:HARV  1  0.035721 0.0357210 0.160118 0.6960800
Residuals 12  2.677109 0.2230924
Burnham Utilisation of NP by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.419077 1.419077 7.322632 0.0190949
     HARV  1  0.054173 0.054173 0.279538 0.6066452
FERT:HARV  1  0.011183 0.011183 0.057706 0.8142136
Residuals 12  2.325519 0.193793
Burnham Utilisation of NP by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.078680 0.0786803 0.312408 0.5864858
     HARV  1  0.527076 0.5270760 2.092811 0.1736055
FERT:HARV  1  0.002550 0.0025503 0.010126 0.9215073
Residuals 12  3.022209 0.2518508
Burnham Utilisation of NP by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.158802 0.1588023 0.974862 0.3429612
     HARV  1  0.608400 0.6084000 3.734873 0.0772342
FERT:HARV  1  0.157212 0.1572122 0.965101 0.3452976
Residuals 12  1.954766 0.1628971
```

3.6.1: KINLEITH ALL SUBSTRATES

Kinleith Utilisation by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.161540	0.1615400	0.331231	0.5720604
HARV	2	0.030372	0.0151861	0.031139	0.9693934
FERT:HARV	2	1.369874	0.6849370	1.404436	0.2711539
Residuals	18	8.778520	0.4876956		

Kinleith Utilisation by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.281450	0.2814500	0.564065	0.4623338
HARV	2	0.018003	0.0090013	0.018040	0.9821396
FERT:HARV	2	1.920815	0.9604075	1.924790	0.1747692
Residuals	18	8.981415	0.4989675		

Kinleith Utilisation by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.277995	0.277995	0.716798	0.4083119
HARV	2	2.474268	1.237134	3.189892	0.0651904
FERT:HARV	2	0.979845	0.489923	1.263242	0.3066347
Residuals	18	6.980930	0.387829		

Kinleith Utilisation by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.321643	1.321643	2.757011	0.1141485
HARV	2	1.616141	0.808070	1.685674	0.2132875
FERT:HARV	2	1.944446	0.972223	2.028104	0.1605738
Residuals	18	8.628755	0.479375		

Kinleith Utilisation by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.487028	1.487028	4.951993	0.03908279
HARV	2	5.496539	2.748270	9.152088	0.00181069
FERT:HARV	2	2.109258	1.054629	3.512049	0.05154976
Residuals	18	5.405198	0.300289		

Kinleith Utilisation by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2.068001	2.068001	4.757102	0.0426858
HARV	2	3.144704	1.572352	3.616942	0.0478185
FERT:HARV	2	0.650758	0.325379	0.748482	0.4872474
Residuals	18	7.824935	0.434719		

Kinleith Utilisation by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.799633	1.799633	6.402388	0.0209442
HARV	2	1.350564	0.675282	2.402389	0.1189104
FERT:HARV	2	1.271856	0.635928	2.262383	0.1328954
Residuals	18	5.059579	0.281088		

Kinleith Utilisation by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.223113	1.223113	4.198851	0.0553163
HARV	2	2.659403	1.329701	4.564759	0.0249157
FERT:HARV	2	0.635021	0.317510	1.089988	0.3574101
Residuals	18	5.243349	0.291297		

3.6.2: KINLEITH AMINO ACIDS

Kinleith Utilisation of AA by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.056648	0.0566482	0.612797	0.4439145
HARV	2	0.024438	0.0122190	0.132181	0.8770254
FERT:HARV	2	0.294325	0.1471625	1.591944	0.2308881
Residuals	18	1.663956	0.0924420		

Kinleith Utilisation of AA by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.087483	0.0874834	1.054559	0.3180625
HARV	2	0.324552	0.1622762	1.956141	0.1703194
FERT:HARV	2	0.025324	0.0126620	0.152633	0.8595443
Residuals	18	1.493231	0.0829573		

Kinleith Utilisation of AA by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.116483	0.1164827	1.453868	0.2435197
HARV	2	0.882686	0.4413430	5.508584	0.0136006
FERT:HARV	2	0.006973	0.0034863	0.043514	0.9575197
Residuals	18	1.442144	0.0801191		

Kinleith Utilisation of AA by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.205905	0.2059054	1.818633	0.1942004
HARV	2	0.362459	0.1812293	1.600685	0.2291803
FERT:HARV	2	0.039088	0.0195439	0.172619	0.8428348
Residuals	18	2.037957	0.1132198		

Kinleith Utilisation of AA by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.103228	0.1032282	1.48276	0.2390666
HARV	2	1.463821	0.7319105	10.51306	0.0009446
FERT:HARV	2	0.591726	0.2958632	4.24974	0.0307834
Residuals	18	1.253144	0.0696191		

Kinleith Utilisation of AA by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.384813	0.3848134	4.035906	0.0597821
HARV	2	0.546264	0.2731322	2.864598	0.0831582
FERT:HARV	2	0.008797	0.0043985	0.046131	0.9550291
Residuals	18	1.716254	0.0953475		

3.6.2: KINLEITH AMINO ACIDS conintued

Kinleith Utilisation of AA by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.300384	0.3003844	6.01523	0.02461102
HARV	2	0.342661	0.1713305	3.43092	0.05465810
FERT:HARV	2	1.070423	0.5352114	10.71768	0.00085997
Residuals	18	0.898871	0.0499373		

Kinleith Utilisation of AA by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.069338	0.0693375	0.785490	0.3871554
HARV	2	0.323651	0.1618254	1.833238	0.1885202
FERT:HARV	2	0.138360	0.0691801	0.783707	0.4716846
Residuals	18	1.588914	0.0882730		

3.6.3: KINLEITH CARBOXYLIC ACIDS

Kinleith Utilisation of CARB by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.083308	0.0833082	0.792892	0.3849746
HARV	2	0.104319	0.0521596	0.496433	0.6167910
FERT:HARV	2	0.651176	0.3255880	3.098808	0.0697428
Residuals	18	1.891239	0.1050688		

Kinleith Utilisation of CARB by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.033750	0.0337500	0.197316	0.6621901
HARV	2	0.020827	0.0104135	0.060882	0.9411273
FERT:HARV	2	0.429725	0.2148624	1.256173	0.3085421
Residuals	18	3.078814	0.1710452		

Kinleith Utilisation of CARB by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.152323	0.1523227	1.408982	0.2506554
HARV	2	0.978722	0.4893612	4.526583	0.0255558
FERT:HARV	2	0.360577	0.1802887	1.667667	0.2165497
Residuals	18	1.945950	0.1081083		

Kinleith Utilisation of CARB by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.167167	0.1671670	2.049773	0.1693646
HARV	2	0.294219	0.1471093	1.803828	0.1931895
FERT:HARV	2	0.254229	0.1271143	1.558653	0.2375231
Residuals	18	1.467971	0.0815539		

Kinleith Utilisation of CARB by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.224460	0.2244600	3.424573	0.08071621
HARV	2	0.909071	0.4545353	6.934816	0.00584870
FERT:HARV	2	1.193145	0.5965725	9.101869	0.00185640
Residuals	18	1.179791	0.0655440		

Kinleith Utilisation of CARB by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.324803	0.3248027	3.764910	0.0681684
HARV	2	0.697745	0.3488727	4.043915	0.0354414
FERT:HARV	2	0.027029	0.0135147	0.156654	0.8561533
Residuals	18	1.552878	0.0862710		

Kinleith Utilisation of CARB by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.207948	0.2079482	1.536728	0.2310248
HARV	2	0.138655	0.0693274	0.512326	0.6075778
FERT:HARV	2	0.238886	0.1194428	0.882677	0.4308351
Residuals	18	2.435737	0.1353187		

Kinleith Utilisation of CARB by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.266072	0.2660720	2.618664	0.1230021
HARV	2	0.240521	0.1202605	1.183596	0.3289061
FERT:HARV	2	0.250303	0.1251515	1.231733	0.3152388
Residuals	18	1.828909	0.1016060		

3.6.4: KINLEITH CARBOHYDRATES

Kinleith Utilisation of CHO by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001944	0.0019440	0.010026	0.9213486
HARV	2	0.024752	0.0123759	0.063826	0.9383792
FERT:HARV	2	0.471941	0.2359704	1.216975	0.3193607
Residuals	18	3.490183	0.1938991		

Kinleith Utilisation of CHO by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.158763	0.1587627	0.830900	0.3740591
HARV	2	0.060601	0.0303005	0.158581	0.8545333
FERT:HARV	2	1.320640	0.6603202	3.455851	0.0536812
Residuals	18	3.439316	0.1910731		

Kinleith Utilisation of CHO by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.015555	0.0155550	0.130329	0.7222936
HARV	2	1.139943	0.5699713	4.775539	0.0216873
FERT:HARV	2	0.373995	0.1869975	1.566770	0.2358860
Residuals	18	2.148340	0.1193522		

Kinleith Utilisation of CHO by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.481667	0.4816667	3.026069	0.0990074
HARV	2	0.808644	0.4043221	2.540152	0.1067281
FERT:HARV	2	0.771270	0.3856350	2.422751	0.1170163
Residuals	18	2.865103	0.1591724		

KINLEITH CARBOHYDRATES continued

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Kinleith Utilisation of CHO by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.651751 0.6517510 5.303201 0.0334335
     HARV  2  1.616249 0.8081247 6.575589 0.0071810
FERT:HARV  2  0.127152 0.0635762 0.517310 0.6047206
Residuals 18  2.212158 0.1228977
Kinleith Utilisation of CHO by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  1.014759 1.014759 6.108415 0.0236661
     HARV  2  0.838327 0.419164 2.523184 0.1081509
FERT:HARV  2  0.412412 0.206206 1.241271 0.3126065
Residuals 18  2.990247 0.166125
Kinleith Utilisation of CHO by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.678721 0.6787207 7.907684 0.0115346
     HARV  2  0.852881 0.4264406 4.968403 0.0191365
FERT:HARV  2  0.253831 0.1269153 1.478673 0.2543466
Residuals 18  1.544950 0.0858305
Kinleith Utilisation of CHO by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.237805 0.2378050 1.571212 0.2260686
     HARV  2  1.000153 0.5000764 3.304076 0.0599434
FERT:HARV  2  0.070952 0.0354760 0.234395 0.7934261
Residuals 18  2.724325 0.1513514
```

3.6.5: KINLEITH NITROGEN AND PHOSPHOROUS SOURCES

```
Kinleith Utilisation of NP by FH Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq   F Value     Pr(F)
     FERT  1  0.043095 0.0430954 0.2916689 0.5957724
     HARV  2  0.117990 0.0589952 0.3992784 0.6765999
FERT:HARV  2  0.061909 0.0309545 0.2094996 0.8129396
Residuals 18  2.659580 0.1477545
Kinleith Utilisation of NP by FH Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.051615 0.0516154 0.374076 0.5484384
     HARV  2  0.280212 0.1401058 1.015400 0.3820918
FERT:HARV  2  0.267987 0.1339936 0.971103 0.3976433
Residuals 18  2.483655 0.1379808
Kinleith Utilisation of NP by Soil Microbes in 2002 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.026534 0.0265335 0.159345 0.6944569
     HARV  2  0.149796 0.0748980 0.449793 0.6447357
FERT:HARV  2  0.510217 0.2551085 1.532032 0.2429814
Residuals 18  2.997296 0.1665164
Kinleith Utilisation of NP by Soil Microbes in 2002 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.510417 0.5104167 2.579597 0.1256495
     HARV  2  0.309072 0.1545361 0.781011 0.4728560
FERT:HARV  2  1.046429 0.5232143 2.644275 0.0984397
Residuals 18  3.561602 0.1978668
Kinleith Utilisation of NP by FH Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value      Pr(F)
     FERT  1  0.620495 0.6204950 6.346755 0.02143084
     HARV  2  1.447685 0.7238425 7.403849 0.00450475
FERT:HARV  2  0.570648 0.2853240 2.918447 0.07983725
Residuals 18  1.759783 0.0977657
Kinleith Utilisation of NP by FH Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.419233 0.4192327 2.833304 0.1095917
     HARV  2  1.275910 0.6379552 4.311498 0.0295216
FERT:HARV  2  0.290046 0.1450232 0.980111 0.3944247
Residuals 18  2.663389 0.1479660
Kinleith Utilisation of NP by Soil Microbes in 2003 (120 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.326667 0.3266667 2.036587 0.1706715
     HARV  2  0.333040 0.1665200 1.038161 0.3743651
FERT:HARV  2  0.229015 0.1145075 0.713891 0.5030874
Residuals 18  2.887184 0.1603991
Kinleith Utilisation of NP by Soil Microbes in 2003 (240 Hours)
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.393216 0.3932160 3.694684 0.0705597
     HARV  2  1.232579 0.6162896 5.790699 0.0114363
FERT:HARV  2  0.168832 0.0844159 0.793177 0.4675952
Residuals 18  1.915695 0.1064275
```

3.7.1: GOLDEN DOWNS ALL SUBSTRATES

Golden Downs Utilisation by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.01242	0.012422	0.017603	0.8959207
HARV	2	4.63361	2.316803	3.283272	0.0608634
FERT:HARV	2	0.23097	0.115486	0.163662	0.8502782
Residuals	18	12.70149	0.705638		

Golden Downs Utilisation by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.29682	0.296815	0.452139	0.5098613
HARV	2	6.69253	3.346264	5.097367	0.0176173
FERT:HARV	2	0.39486	0.197432	0.300748	0.7439124
Residuals	18	11.81644	0.656469		

Golden Downs Utilisation by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.081550	0.0815500	0.1550738	0.6983590
HARV	2	0.816803	0.4084013	0.7766070	0.4747765
FERT:HARV	2	0.234671	0.1173353	0.2231222	0.8021968
Residuals	18	9.465822	0.5258790		

Golden Downs Utilisation by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.01887	0.0188720	0.0259773	0.8737510
HARV	2	0.61333	0.3066668	0.4221256	0.6619765
FERT:HARV	2	0.48863	0.2443135	0.3362966	0.7188046
Residuals	18	13.07668	0.7264824		

Golden Downs Utilisation by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.580637	0.580637	2.78025	0.1127367
HARV	2	6.335697	3.167849	15.16856	0.0001377
FERT:HARV	2	1.264626	0.632313	3.02769	0.0735430
Residuals	18	3.759176	0.208843		

Golden Downs Utilisation by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.178193	0.1781927	0.550862	0.4675410
HARV	2	1.903820	0.9519099	2.942720	0.0783887
FERT:HARV	2	1.152345	0.5761725	1.781171	0.1968743
Residuals	18	5.822632	0.3234796		

Golden Downs Utilisation by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.113025	0.113025	0.261368	0.6153960
HARV	2	2.260301	1.130150	2.613438	0.1008173
FERT:HARV	2	1.903067	0.951533	2.200392	0.1396637
Residuals	18	7.783885	0.432438		

Golden Downs Utilisation by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.005310	0.0053104	0.015887	0.9010943
HARV	2	0.825014	0.4125072	1.234101	0.3145831
FERT:HARV	2	1.305292	0.6526460	1.952526	0.1708260
Residuals	18	6.016630	0.3342572		

3.7.2: GOLDEN DOWNS AMINO ACIDS

Golden Downs Utilisation of AA by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.013776	0.0137760	0.105744	0.7487918
HARV	2	0.748429	0.3742145	2.872448	0.0826647
FERT:HARV	2	0.041670	0.0208350	0.159929	0.8534023
Residuals	18	2.344990	0.1302772		

Golden Downs Utilisation of AA by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.178883	0.1788827	1.533199	0.2315399
HARV	2	0.953749	0.4768747	4.087281	0.0343984
FERT:HARV	2	0.047324	0.0236622	0.202808	0.8182752
Residuals	18	2.100111	0.1166728		

Golden Downs Utilisation of AA by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.031248	0.0312482	0.289775	0.5969593
HARV	2	0.242126	0.1210632	1.122660	0.3471608
FERT:HARV	2	0.217537	0.1087687	1.008649	0.3844178
Residuals	18	1.941048	0.1078360		

Golden Downs Utilisation of AA by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.006733	0.0067335	0.0450735	0.8342546
HARV	2	0.146705	0.0733526	0.4910162	0.6199664
FERT:HARV	2	0.025678	0.0128389	0.0859423	0.9180214
Residuals	18	2.689009	0.1493894		

Golden Downs Utilisation of AA by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.071395	0.0713950	1.82901	0.1929921
HARV	2	0.618340	0.3091702	7.92036	0.0034080
FERT:HARV	2	1.125370	0.5626852	14.41494	0.0001831
Residuals	18	0.702627	0.0390348		

Golden Downs Utilisation of AA by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001734	0.0017340	0.026048	0.8735804
HARV	2	0.079292	0.0396462	0.595566	0.5617553
FERT:HARV	2	0.417807	0.2089035	3.138155	0.0677343
Residuals	18	1.198240	0.0665689		

GOLDEN DOWNS AMINO ACIDS continued

Golden Downs Utilisation of AA by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.175446	0.1754460	2.142140	0.1605467
HARV	2	0.155271	0.0776355	0.947905	0.4060673
FERT:HARV	2	0.641521	0.3207605	3.916383	0.0387181
Residuals	18	1.474240	0.0819022		

Golden Downs Utilisation of AA by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.019723	0.01972267	0.2077852	0.6539603
HARV	2	0.175954	0.08797704	0.9268687	0.4138777
FERT:HARV	2	0.113415	0.05670754	0.5974337	0.5607722
Residuals	18	1.708534	0.09491856		

3.7.3: GOLDEN DOWNS CARBOXYLIC ACIDS

Golden Downs Utilisation of CARB by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.051523	0.0515227	0.280924	0.6025736
HARV	2	1.126724	0.5633621	3.071697	0.0711652
FERT:HARV	2	0.050776	0.0253878	0.138425	0.8716462
Residuals	18	3.301276	0.1834042		

Golden Downs Utilisation of CARB by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.005400	0.0054000	0.027010	0.8712896
HARV	2	1.138502	0.5692510	2.847296	0.0842577
FERT:HARV	2	0.071097	0.0355486	0.177808	0.8385555
Residuals	18	3.598684	0.1999269		

Golden Downs Utilisation of CARB by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.102966	0.1029660	0.7533514	0.3968419
HARV	2	0.059058	0.0295292	0.2160503	0.8077539
FERT:HARV	2	0.220059	0.1100295	0.8050316	0.4625318
Residuals	18	2.460191	0.1366773		

Golden Downs Utilisation of CARB by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.049504	0.0495042	0.368558	0.5513734
HARV	2	0.379313	0.1896565	1.411989	0.2693885
FERT:HARV	2	0.351415	0.1757073	1.308138	0.2948226
Residuals	18	2.417736	0.1343187		

Golden Downs Utilisation of CARB by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.141681	0.1416807	2.43986	0.1356968
HARV	2	1.434423	0.7172116	12.35097	0.0004202
FERT:HARV	2	0.033706	0.0168528	0.29022	0.7515348
Residuals	18	1.045246	0.0580692		

Golden Downs Utilisation of CARB by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.010668	0.0106682	0.079513	0.7811744
HARV	2	0.849339	0.4246693	3.165200	0.0663910
FERT:HARV	2	0.036583	0.0182915	0.136333	0.8734446
Residuals	18	2.415028	0.1341682		

Golden Downs Utilisation of CARB by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.322712	0.3227120	2.905993	0.1054500
HARV	2	0.606991	0.3034953	2.732948	0.0919429
FERT:HARV	2	0.076111	0.0380555	0.342687	0.7143918
Residuals	18	1.998909	0.1110505		

Golden Downs Utilisation of CARB by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.112340	0.1123402	1.352473	0.2600327
HARV	2	0.267321	0.1336607	1.609152	0.2275393
FERT:HARV	2	0.105614	0.0528072	0.635750	0.5410194
Residuals	18	1.495130	0.0830628		

3.7.4: GOLDEN DOWNS CARBOHYDRATES

Golden Downs Utilisation of CHO by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.001650	0.0016500	0.006744	0.9354581
HARV	2	1.055856	0.5279280	2.157602	0.1445589
FERT:HARV	2	0.059096	0.0295480	0.120761	0.8869581
Residuals	18	4.404291	0.2446828		

Golden Downs Utilisation of CHO by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.260000	0.2600002	1.001645	0.3301780
HARV	2	1.351765	0.6758827	2.603824	0.1015716
FERT:HARV	2	0.165686	0.0828432	0.319152	0.7307944
Residuals	18	4.672316	0.2595731		

Golden Downs Utilisation of CHO by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.095004	0.0950042	0.4313802	0.5196223
HARV	2	0.430134	0.2150671	0.9765435	0.3956960
FERT:HARV	2	0.286079	0.1430395	0.6494918	0.5341246
Residuals	18	3.964194	0.2202330		

Golden Downs Utilisation of CHO by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.168505	0.1685050	0.5528650	0.4667448
HARV	2	0.388138	0.1940690	0.6367405	0.5405192
FERT:HARV	2	0.557832	0.2789158	0.9151227	0.4183114
Residuals	18	5.486132	0.3047851		

GOLDEN DOWNS CARBOHYDRATES continued

Golden Downs Utilisation of CHO by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.232657	0.232657	3.79025	0.0673287
HARV	2	2.612959	1.306479	21.28407	0.0000181
FERT:HARV	2	0.176266	0.088133	1.43579	0.2639092
Residuals	18	1.104893	0.061383		

Golden Downs Utilisation of CHO by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.010668	0.0106682	0.079513	0.7811744
HARV	2	0.849339	0.4246693	3.165200	0.0663910
FERT:HARV	2	0.036583	0.0182915	0.136333	0.8734446
Residuals	18	2.415028	0.1341682		

Golden Downs Utilisation of CHO by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.117880	0.1178802	0.684966	0.4187200
HARV	2	0.758501	0.3792503	2.203707	0.1392922
FERT:HARV	2	0.393186	0.1965930	1.142342	0.3411445
Residuals	18	3.097737	0.1720965		

Golden Downs Utilisation of CHO by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.225816	0.2258160	1.393634	0.2531578
HARV	2	0.262917	0.1314586	0.811303	0.4598776
FERT:HARV	2	0.461261	0.2306304	1.423347	0.2667583
Residuals	18	2.916610	0.1620339		

3.7.5: GOLDEN DOWNS NITROGEN AND PHOSPHOROUS SOURCES

Golden Downs Utilisation of NP by FH Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.012881	0.0128807	0.066955	0.7987582
HARV	2	1.812610	0.9063049	4.711094	0.0226221
FERT:HARV	2	0.115644	0.0578220	0.300567	0.7440427
Residuals	18	3.462782	0.1923768		

Golden Downs Utilisation of NP by FH Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.215083	0.215083	1.242425	0.2796661
HARV	2	2.194354	1.097177	6.337843	0.0082472
FERT:HARV	2	0.270441	0.135220	0.781100	0.4728171
Residuals	18	3.116073	0.173115		

Golden Downs Utilisation of NP by Soil Microbes in 2002 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.003725	0.0037250	0.0210943	0.8861363
HARV	2	0.175408	0.0877040	0.4966534	0.6166622
FERT:HARV	2	0.020684	0.0103422	0.0585660	0.9432950
Residuals	18	3.178619	0.1765900		

Golden Downs Utilisation of NP by Soil Microbes in 2002 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.021660	0.0216600	0.0983933	0.7573723
HARV	2	0.208015	0.1040075	0.4724666	0.6309789
FERT:HARV	2	0.066614	0.0333070	0.1513012	0.8606705
Residuals	18	3.962472	0.2201373		

Golden Downs Utilisation of NP by FH Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.090037	0.0900375	0.982863	0.3346339
HARV	2	1.792065	0.8960326	9.781227	0.0013325
FERT:HARV	2	0.451310	0.2256551	2.463285	0.1133446
Residuals	18	1.648933	0.0916074		

Golden Downs Utilisation of NP by FH Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.004347	0.0043470	0.042174	0.8395927
HARV	2	0.329319	0.1646595	1.597495	0.2298018
FERT:HARV	2	1.322759	0.6613793	6.416575	0.0078757
Residuals	18	1.855324	0.1030736		

Golden Downs Utilisation of NP by Soil Microbes in 2003 (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.000001	0.0000015	0.000009	0.9976719
HARV	2	0.901763	0.4508814	2.631228	0.0994380
FERT:HARV	2	0.889824	0.4449121	2.596393	0.1021589
Residuals	18	3.084440	0.1713578		

Golden Downs Utilisation of NP by Soil Microbes in 2003 (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.236612	0.2366120	2.156888	0.1591915
HARV	2	0.313889	0.1569447	1.430663	0.2650791
FERT:HARV	2	0.515041	0.2575207	2.347485	0.1241899
Residuals	18	1.974612	0.1097007		

3.8.1: CORRELATIONS BETWEEN POSITIONS ON PRINCIPAL AXIS OF FH LITTER MICROBIAL COMMUNITY AND ENVIRNMENTAL PARAMETERS

r^2 Values for FH Bacteria in 2002 (120 Hours)

	F120 2002	FH % H_2O 2002
F120 2002	1	
FH % H_2O 2002	0.24060	1

r^2 Values for FH Bacteria in 2002 (240 Hours)

	F240 2002	FH % H_2O 2002
F240 2002	1	
FH % H_2O 2002	0.61059	1

r^2 Values for FH Bacteria in 2003 (120 Hours)

	F120 2003	FH % H_2O 2003
F120 2003	1	
FH % H_2O 2003	0.42213	1

r^2 Values for FH Bacteria in 2003 (240 Hours)

	F240 2003	FH % H_2O 2003
F240 2003	1	
FH % H_2O 2003	0.62530	1

3.8.2: CORRELATIONS BETWEEN POSITIONS ON PRINCIPAL AXIS OF SOIL MICROBIAL COMMUNITY AND ENVIRNMENTAL PARAMETERS

r^2 Values for Soil Bacteria in 2002 (120 Hours)

	S120 2002	Soil % Carbon 2002
S120 2002	1	
Soil % Carbon 2002	0.50007	1

r^2 Values for Soil Bacteria in 2002 (240 Hours)

	S240 2002	Soil % H_2O 2002
S240 2002	1	
Soil % H_2O 2002	0.67768	1

r^2 Values for Soil Bacteria in 2003 (120 Hours)

	S120 2003	FH % H_2O 2003
S120 2003	1	
FH % H_2O 2003	0.40494	1

r^2 Values for Soil Bacteria in 2003 (240 Hours)

	S240 2003	Soil % H_2O 2003
S240 2003	1	
Soil % H_2O 2003	0.45499	1

STATISTICAL APPENDIX FOUR: FH Litter and Soil Microbial Community Substrate Utilisation ANOVA Outputs

4.1.1: FERTILISATION AT ALL SITES SUMMER 2002

All Sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	495.9957	99.19913	20.79760	0.0000000
FERT	1	0.0135	0.01347	0.00282	0.9577215
SITE:FERT	5	45.7562	9.15125	1.91861	0.0969094
Residuals	110	524.6714	4.76974		

All Sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1621.351	324.2702	40.42384	0.0000000
FERT	1	6.030	6.0298	0.75169	0.3878301
SITE:FERT	5	118.647	23.7295	2.95814	0.0152106
Residuals	110	882.393	8.0218		

All Sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	17.03214	3.406428	19.86754	0.0000000
FERT	1	0.14763	0.147635	0.86106	0.3554741
SITE:FERT	5	1.25509	0.251019	1.46404	0.2074163
Residuals	110	18.86026	0.171457		

All Sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	32.79443	6.558886	17.80585	0.0000000
FERT	1	0.00008	0.000084	0.00023	0.9879480
SITE:FERT	5	5.77515	1.155030	3.13564	0.0110071
Residuals	110	40.51912	0.368356		

All Sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	55.97148	11.19430	19.51648	0.0000000
FERT	1	0.14306	0.14306	0.24941	0.6184897
SITE:FERT	5	3.71259	0.74252	1.29453	0.2714838
Residuals	110	63.09398	0.57358		

All Sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	27.15909	5.431818	17.18281	0.0000000
FERT	1	0.01425	0.014246	0.04507	0.8322769
SITE:FERT	5	2.06279	0.412558	1.30507	0.2670577
Residuals	110	34.77312	0.316119		

All Sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	41.24905	8.249809	37.32816	0.00000000
FERT	1	0.62225	0.622246	2.81550	0.09619706
SITE:FERT	5	3.52955	0.705911	3.19405	0.00989352
Residuals	110	24.31084	0.221008		

All Sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	57.86767	11.57353	22.41198	0.0000000
FERT	1	0.01703	0.01703	0.03297	0.8562468
SITE:FERT	5	8.69755	1.73951	3.36854	0.0071909
Residuals	110	56.80394	0.51640		

All Sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	312.1172	62.42344	39.20621	0.0000000
FERT	1	0.8747	0.87470	0.54937	0.4601540
SITE:FERT	5	14.1437	2.82875	1.77665	0.1235126
Residuals	110	175.1401	1.59218		

All Sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	85.20928	17.04186	37.01053	0.0000000
FERT	1	0.36116	0.36116	0.78435	0.3777464
SITE:FERT	5	5.87054	1.17411	2.54986	0.0318296
Residuals	110	50.65056	0.46046		

All Sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	284.2362	56.84725	46.09336	0.0000000
FERT	1	1.3867	1.38666	1.12434	0.2913084
SITE:FERT	5	13.2346	2.64691	2.14619	0.0652292
Residuals	110	135.6637	1.23331		

All Sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	496.3099	99.26198	40.58201	0.0000000
FERT	1	1.4314	1.43140	0.58521	0.4459160
SITE:FERT	5	27.6499	5.52999	2.26087	0.0532922
Residuals	110	269.0556	2.44596		

All Sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.485130	0.4970261	10.57441	0.0000000
FERT	1	0.009197	0.0091967	0.19566	0.6591131
SITE:FERT	5	0.374574	0.0749148	1.59384	0.1677542
Residuals	110	5.170298	0.0470027		

All Sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	14.98816	2.997632	18.45008	0.0000000
FERT	1	0.18572	0.185717	1.14307	0.2873455
SITE:FERT	5	1.69534	0.339067	2.08692	0.0723655
Residuals	110	17.87198	0.162473		

FERTILISATION AT ALL SITES SUMMER 2002 continued

All Sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	59.43171	11.88634	82.51022	0.0000000
FERT	1	0.21968	0.21968	1.52490	0.2195105
SITE:FERT	5	1.40244	0.28049	1.94704	0.0922738
Residuals	110	15.84649	0.14406		

All Sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	14.93432	2.986864	37.16180	0.0000000
FERT	1	0.06661	0.066614	0.82879	0.3646126
SITE:FERT	5	0.55238	0.110475	1.37451	0.2394001
Residuals	110	8.84120	0.080375		

All Sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	7.651001	1.530200	22.69441	0.0000000
FERT	1	0.002750	0.002750	0.04079	0.8403185
SITE:FERT	5	0.313953	0.062791	0.93125	0.4637241
Residuals	110	7.416892	0.067426		

All Sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	19.40921	3.881841	21.00043	0.0000000
FERT	1	0.05261	0.052612	0.28463	0.5947617
SITE:FERT	5	1.05625	0.211250	1.14285	0.3422008
Residuals	110	20.33304	0.184846		

All Sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	109.0561	21.81122	50.40972	0.0000000
FERT	1	0.4515	0.45145	1.04339	0.3092762
SITE:FERT	5	6.2999	1.25998	2.91204	0.0165403
Residuals	110	47.5947	0.43268		

All Sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	24.57460	4.914919	26.74264	0.0000000
FERT	1	0.12081	0.120811	0.65735	0.4192492
SITE:FERT	5	1.91416	0.382831	2.08303	0.0728593
Residuals	110	20.21644	0.183786		

4.1.2: FERTILISATION AT ALL SITES SUMMER 2003

All Sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1875.569	375.1139	173.4137	0.0000000
FERT	1	9.598	9.5976	4.4369	0.0374436
SITE:FERT	5	5.939	1.1878	0.5491	0.7386838
Residuals	110	237.943	2.1631		

All Sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2208.677	441.7353	138.2925	0.0000000
FERT	1	10.266	10.2665	3.2141	0.0757555
SITE:FERT	5	18.436	3.6872	1.1543	0.3363675
Residuals	110	351.363	3.1942		

All Sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	43.05401	8.610803	97.36606	0.0000000
FERT	1	0.34756	0.347558	3.92999	0.0499257
SITE:FERT	5	0.10787	0.021574	0.24395	0.9420201
Residuals	110	9.72812	0.088437		

All Sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	83.60574	16.72115	89.85119	0.0000000
FERT	1	1.10413	1.10413	5.93307	0.0164652
SITE:FERT	5	0.47637	0.09527	0.51196	0.7667191
Residuals	110	20.47081	0.18610		

All Sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	346.9122	69.38245	278.8740	0.0000000
FERT	1	0.5076	0.50757	2.0401	0.1560321
SITE:FERT	5	0.5003	0.10006	0.4022	0.8464184
Residuals	110	27.3674	0.24879		

All Sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	88.43528	17.68706	128.1953	0.0000000
FERT	1	0.55538	0.55538	4.0254	0.0472734
SITE:FERT	5	0.80397	0.16079	1.1654	0.3308185
Residuals	110	15.17665	0.13797		

All Sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	48.19080	9.638160	111.3454	0.0000000
FERT	1	0.43909	0.439091	5.0726	0.0262916
SITE:FERT	5	0.48710	0.097419	1.1254	0.3511804
Residuals	110	9.52170	0.086561		

FERTILISATION AT ALL SITES SUMMER 2003 continued

All Sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	96.30283	19.26057	91.64670	0.0000000
FERT	1	1.02884	1.02884	4.89548	0.0289931
SITE:FERT	5	0.40251	0.08050	0.38305	0.8594930
Residuals	110	23.11771	0.21016		

All Sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	421.4086	84.28171	138.3560	0.0000000
FERT	1	1.4032	1.40315	2.3034	0.1319598
SITE:FERT	5	5.1547	1.03094	1.6924	0.1423680
Residuals	110	67.0082	0.60917		

All Sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	101.1602	20.23205	109.9676	0.0000000
FERT	1	0.1174	0.11739	0.6381	0.4261314
SITE:FERT	5	0.8892	0.17785	0.9667	0.4415274
Residuals	110	20.2380	0.18398		

All Sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	641.3108	128.2622	209.7844	0.0000000
FERT	1	0.0000	0.0000	0.0001	0.9934611
SITE:FERT	5	2.4181	0.4836	0.7910	0.5583603
Residuals	110	67.2540	0.6114		

All Sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	453.0353	90.60707	81.90569	0.0000000
FERT	1	0.0399	0.03992	0.03609	0.8496894
SITE:FERT	5	8.0586	1.61171	1.45693	0.2098093
Residuals	110	121.6860	1.10624		

All Sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	13.52551	2.705103	119.3456	0.0000000
FERT	1	0.00909	0.009091	0.4011	0.5278388
SITE:FERT	5	0.20193	0.040386	1.7818	0.1224385
Residuals	110	2.49327	0.022666		

All Sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	38.12163	7.624326	110.0563	0.0000000
FERT	1	0.00523	0.005229	0.0755	0.7840246
SITE:FERT	5	0.12755	0.025511	0.3682	0.8693889
Residuals	110	7.62042	0.069277		

All Sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	93.69940	18.73988	220.4574	0.0000000
FERT	1	0.00656	0.00656	0.0772	0.7816867
SITE:FERT	5	0.15020	0.03004	0.3534	0.8791076
Residuals	110	9.35050	0.08500		

All Sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	35.71495	7.142989	176.6778	0.0000000
FERT	1	0.00266	0.002656	0.0657	0.7981819
SITE:FERT	5	0.38493	0.076986	1.9042	0.0993390
Residuals	110	4.44724	0.040429		

All Sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	11.61266	2.322532	71.79996	0.0000000
FERT	1	0.05351	0.053509	1.65420	0.2010884
SITE:FERT	5	0.21770	0.043541	1.34605	0.2504243
Residuals	110	3.55820	0.032347		

All Sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	22.21262	4.442525	52.86383	0.0000000
FERT	1	0.00900	0.009000	0.10710	0.7440906
SITE:FERT	5	0.49143	0.098285	1.16954	0.3287796
Residuals	110	9.24408	0.084037		

All Sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	81.60177	16.32035	68.61147	0.0000000
FERT	1	0.59565	0.59565	2.50413	0.1164194
SITE:FERT	5	1.53240	0.30648	1.28846	0.2740619
Residuals	110	26.16529	0.23787		

All Sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	20.13560	4.027120	52.38940	0.0000000
FERT	1	0.06041	0.060415	0.78594	0.3772638
SITE:FERT	5	0.55390	0.110781	1.44116	0.2152097
Residuals	110	8.45559	0.076869		

4.1.3: FERTILISATION AT ALL SITES SUMMER 2002 and 2003

All Sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	311.648	311.6480	89.9047	0.0000000
SITE	5	1972.922	394.5844	113.8302	0.0000000
FERT	1	5.165	5.1650	1.4900	0.2235208
YEAR:SITE	5	398.643	79.7286	23.0002	0.0000000
YEAR:FERT	1	4.446	4.4460	1.2826	0.2586497
SITE:FERT	5	25.103	5.0205	1.4483	0.2080675
YEAR:SITE:FERT	5	26.593	5.3185	1.5343	0.1802080
Residuals	220	762.614	3.4664		

All Sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	1860.592	1860.592	331.7757	0.0000000
SITE	5	3173.278	634.656	113.1700	0.0000000
FERT	1	16.016	16.016	2.8560	0.0924527
YEAR:SITE	5	656.749	131.350	23.4219	0.0000000
YEAR:FERT	1	0.280	0.280	0.0500	0.8233422
SITE:FERT	5	60.991	12.198	2.1752	0.0579415
YEAR:SITE:FERT	5	76.092	15.218	2.7137	0.0210975
Residuals	220	1233.756	5.608		

All Sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	12.28600	12.28600	94.54614	0.0000000
SITE	5	54.37961	10.87592	83.69495	0.0000000
FERT	1	0.47412	0.47412	3.64854	0.0574190
YEAR:SITE	5	5.70654	1.14131	8.78287	0.0000001
YEAR:FERT	1	0.02108	0.02108	0.16219	0.6875422
SITE:FERT	5	0.72176	0.14435	1.11084	0.3554857
YEAR:SITE:FERT	5	0.64121	0.12824	0.98688	0.4265919
Residuals	220	28.58838	0.12995		

All Sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	25.8303	25.83031	93.17389	0.0000000
SITE	5	101.2147	20.24293	73.01935	0.0000000
FERT	1	0.5425	0.54245	1.95671	0.1632734
YEAR:SITE	5	15.1855	3.03710	10.95529	0.0000000
YEAR:FERT	1	0.5618	0.56176	2.02637	0.1560060
SITE:FERT	5	3.5899	0.71797	2.58984	0.0267011
YEAR:SITE:FERT	5	2.6617	0.53233	1.92020	0.0920278
Residuals	220	60.9899	0.27723		

All Sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	18.6381	18.63814	45.3275	0.0000000
SITE	5	306.0934	61.21869	148.8824	0.0000000
FERT	1	0.0558	0.05585	0.1358	0.7128244
YEAR:SITE	5	96.7903	19.35806	47.0783	0.0000000
YEAR:FERT	1	0.5948	0.59478	1.4465	0.2303864
SITE:FERT	5	1.7674	0.35348	0.8597	0.5090490
YEAR:SITE:FERT	5	2.4455	0.48909	1.1895	0.3152586
Residuals	220	90.4614	0.41119		

All Sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	22.55266	22.55266	99.33148	0.0000000
SITE	5	95.00994	19.00199	83.69281	0.0000000
FERT	1	0.37376	0.37376	1.64622	0.2008244
YEAR:SITE	5	20.58444	4.11689	18.13252	0.0000000
YEAR:FERT	1	0.19587	0.19587	0.86268	0.3540088
SITE:FERT	5	1.22180	0.24436	1.07626	0.3743756
YEAR:SITE:FERT	5	1.64496	0.32899	1.44902	0.2078264
Residuals	220	49.94978	0.22704		

All Sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	40.31755	40.31755	262.1695	0.0000000
SITE	5	77.30127	15.46025	100.5321	0.0000000
FERT	1	1.05338	1.05338	6.8497	0.0094807
YEAR:SITE	5	12.13858	2.42772	15.7865	0.0000000
YEAR:FERT	1	0.00796	0.00796	0.0518	0.8202221
SITE:FERT	5	2.45743	0.49149	3.1959	0.0083211
YEAR:SITE:FERT	5	1.55921	0.31184	2.0278	0.0758202
Residuals	220	33.83255	0.15378		

All Sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	50.5960	50.59601	139.2754	0.0000000
SITE	5	123.7289	24.74578	68.1176	0.0000000
FERT	1	0.6553	0.65529	1.8038	0.1806376
YEAR:SITE	5	30.4416	6.08832	16.7593	0.0000000
YEAR:FERT	1	0.3906	0.39058	1.0751	0.3009243
SITE:FERT	5	4.0227	0.80454	2.2147	0.0538789
YEAR:SITE:FERT	5	5.0774	1.01547	2.7953	0.0180500
Residuals	220	79.9217	0.36328		

FERTILISATION AT ALL SITES SUMMER 2002 and 2003 continued

All Sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	368.4635	368.4635	334.7617	0.0000000
SITE	5	602.0650	120.4130	109.3993	0.0000000
FERT	1	2.2468	2.2468	2.0413	0.1544995
YEAR:SITE	5	131.4608	26.2922	23.8873	0.0000000
YEAR:FERT	1	0.0311	0.0311	0.0282	0.8667200
SITE:FERT	5	8.5417	1.7083	1.5521	0.1748722
YEAR:SITE:FERT	5	10.7567	2.1513	1.9546	0.0865266
Residuals	220	242.1483	1.1007		

All Sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	109.7561	109.7561	340.6239	0.0000000
SITE	5	154.3262	30.8652	95.7891	0.0000000
FERT	1	0.4452	0.4452	1.3816	0.2410968
YEAR:SITE	5	32.0433	6.4087	19.8891	0.0000000
YEAR:FERT	1	0.0334	0.0334	0.1036	0.7479027
SITE:FERT	5	2.5773	0.5155	1.5997	0.1612781
YEAR:SITE:FERT	5	4.1825	0.8365	2.5960	0.0263889
Residuals	220	70.8886	0.3222		

All Sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	282.7492	282.7492	306.5520	0.0000000
SITE	5	465.9690	93.1938	101.0392	0.0000000
FERT	1	0.7009	0.7009	0.7599	0.3843048
YEAR:SITE	5	459.5781	91.9156	99.6534	0.0000000
YEAR:FERT	1	0.6858	0.6858	0.7435	0.3894753
SITE:FERT	5	10.3562	2.0712	2.2456	0.0508846
YEAR:SITE:FERT	5	5.2964	1.0593	1.1485	0.3357724
Residuals	220	202.9177	0.9224		

All Sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	573.8302	573.8302	323.0847	0.0000000
SITE	5	607.2250	121.4450	68.3774	0.0000000
FERT	1	0.9747	0.9747	0.5488	0.4596042
YEAR:SITE	5	342.1203	68.4241	38.5249	0.0000000
YEAR:FERT	1	0.4966	0.4966	0.2796	0.5974887
SITE:FERT	5	31.5042	6.3008	3.5476	0.0041808
YEAR:SITE:FERT	5	4.2043	0.8409	0.4734	0.7958596
Residuals	220	390.7416	1.7761		

All Sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	7.643439	7.643439	219.4221	0.0000000
SITE	5	8.329206	1.665841	47.8217	0.0000000
FERT	1	0.000000	0.000000	0.0000	0.9983355
YEAR:SITE	5	7.681437	1.536287	44.1026	0.0000000
YEAR:FERT	1	0.018288	0.018288	0.5250	0.4694896
SITE:FERT	5	0.223387	0.044677	1.2826	0.2723916
YEAR:SITE:FERT	5	0.353119	0.070624	2.0274	0.0758721
Residuals	220	7.663571	0.034834		

All Sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	19.68856	19.68856	169.9127	0.0000000
SITE	5	29.47452	5.89490	50.8732	0.0000000
FERT	1	0.12664	0.12664	1.0929	0.2969804
YEAR:SITE	5	23.63527	4.72705	40.7946	0.0000000
YEAR:FERT	1	0.06431	0.06431	0.5550	0.4570812
SITE:FERT	5	1.15652	0.23130	1.9962	0.0802850
YEAR:SITE:FERT	5	0.66638	0.13328	1.1502	0.3348950
Residuals	220	25.49240	0.11587		

All Sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	30.73637	30.73637	268.3654	0.0000000
SITE	5	74.69370	14.93874	130.4331	0.0000000
FERT	1	0.15108	0.15108	1.3191	0.2519996
YEAR:SITE	5	78.43742	15.68748	136.9706	0.0000000
YEAR:FERT	1	0.07516	0.07516	0.6562	0.4187785
SITE:FERT	5	1.06366	0.21273	1.8574	0.1029250
YEAR:SITE:FERT	5	0.48898	0.09780	0.8539	0.5130173
Residuals	220	25.19699	0.11453		

All Sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	16.12391	16.12391	266.9432	0.0000000
SITE	5	25.67517	5.13503	85.0143	0.0000000
FERT	1	0.02133	0.02133	0.3532	0.5529264
YEAR:SITE	5	24.97410	4.99482	82.6929	0.0000000
YEAR:FERT	1	0.04794	0.04794	0.7936	0.3739774
SITE:FERT	5	0.73679	0.14736	2.4396	0.0354480
YEAR:SITE:FERT	5	0.20052	0.04010	0.6640	0.6511831
Residuals	220	13.28845	0.06040		

FERTILISATION AT ALL SITES SUMMER 2002 and 2003 continued

All Sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	6.00877	6.008770	120.4482	0.0000000
SITE	5	12.98614	2.597227	52.0624	0.0000000
FERT	1	0.04026	0.040261	0.8070	0.3699785
YEAR:SITE	5	6.27752	1.255505	25.1671	0.0000000
YEAR:FERT	1	0.01600	0.015999	0.3207	0.5717668
SITE:FERT	5	0.26651	0.053303	1.0685	0.3787290
YEAR:SITE:FERT	5	0.26514	0.053029	1.0630	0.3818278
Residuals	220	10.97509	0.049887		

All Sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	19.47080	19.47080	144.8273	0.0000000
SITE	5	28.10563	5.62113	41.8109	0.0000000
FERT	1	0.00905	0.00905	0.0673	0.7955799
YEAR:SITE	5	13.51620	2.70324	20.1072	0.0000000
YEAR:FERT	1	0.05257	0.05257	0.3910	0.5324209
SITE:FERT	5	1.39853	0.27971	2.0805	0.0688983
YEAR:SITE:FERT	5	0.14915	0.02983	0.2219	0.9528457
Residuals	220	29.57712	0.13444		

All Sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	136.8261	136.8261	408.1039	0.0000000
SITE	5	113.2588	22.6518	67.5622	0.0000000
FERT	1	1.0421	1.0421	3.1083	0.0792849
YEAR:SITE	5	77.3991	15.4798	46.1708	0.0000000
YEAR:FERT	1	0.0050	0.0050	0.0149	0.9030311
SITE:FERT	5	6.9113	1.3823	4.1228	0.0013406
YEAR:SITE:FERT	5	0.9210	0.1842	0.5494	0.7386741
Residuals	220	73.7600	0.3353		

All Sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
YEAR	1	29.09128	29.09128	223.2168	0.0000000
SITE	5	29.51699	5.90340	45.2967	0.0000000
FERT	1	0.00518	0.00518	0.0397	0.8421611
YEAR:SITE	5	15.19320	3.03864	23.3154	0.0000000
YEAR:FERT	1	0.17605	0.17605	1.3508	0.2463987
SITE:FERT	5	2.11765	0.42353	3.2497	0.0074929
YEAR:SITE:FERT	5	0.35041	0.07008	0.5377	0.7475635
Residuals	220	28.67203	0.13033		

4.2.1: WT and SO HARVESTING AT ALL SITES SUMMER 2002

WT/SO plots FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	396.1190	79.22381	14.17530	0.0000000
FERT	1	1.4132	1.41325	0.25287	0.6166874
HARV	1	0.4968	0.49683	0.08890	0.7664945
SITE:FERT	5	37.3825	7.47651	1.33775	0.2589956
SITE:HARV	5	15.6285	3.12569	0.55927	0.7307666
FERT:HARV	1	11.8167	11.81675	2.11434	0.1505253
SITE:FERT:HARV	5	5.4644	1.09287	0.19554	0.9632108
Residuals	68	380.0427	5.58886		

WT/SO plots FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1112.895	222.5789	28.25407	0.0000000
FERT	1	0.241	0.2406	0.03055	0.8617776
HARV	1	0.000	0.0000	0.00000	0.9989448
SITE:FERT	5	109.146	21.8292	2.77098	0.0245149
SITE:HARV	5	17.572	3.5145	0.44613	0.8146425
FERT:HARV	1	14.359	14.3589	1.82271	0.1814675
SITE:FERT:HARV	5	34.438	6.8877	0.87432	0.5030840
Residuals	68	535.688	7.8778		

WT/SO plots FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	13.64125	2.728250	14.40661	0.0000000
FERT	1	0.01413	0.014129	0.07461	0.7855724
HARV	1	0.03697	0.036972	0.19523	0.6599988
SITE:FERT	5	1.11680	0.223360	1.17946	0.3283910
SITE:HARV	5	0.85692	0.171383	0.90500	0.4830886
FERT:HARV	1	0.40238	0.402384	2.12480	0.1495343
SITE:FERT:HARV	5	0.41340	0.082681	0.43660	0.8214768
Residuals	68	12.87749	0.189375		

WT/SO plots FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	24.76548	4.953096	11.91526	0.0000000
FERT	1	0.17796	0.177965	0.42812	0.5151219
HARV	1	0.00196	0.001960	0.00472	0.9454545
SITE:FERT	5	4.39355	0.878711	2.11384	0.0742105
SITE:HARV	5	1.30597	0.261194	0.62833	0.6786933
FERT:HARV	1	0.82555	0.825548	1.98595	0.1633215
SITE:FERT:HARV	5	0.19581	0.039163	0.09421	0.9928480
Residuals	68	28.26715	0.415693		

WT/SO plots FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	46.78045	9.356091	13.44562	0.0000000
FERT	1	0.55682	0.556817	0.80020	0.3741889
HARV	1	0.07848	0.078483	0.11279	0.7380259
SITE:FERT	5	3.07027	0.614053	0.88245	0.4977299
SITE:HARV	5	2.13361	0.426721	0.61324	0.6900514
FERT:HARV	1	1.09003	1.090026	1.56647	0.2150082
SITE:FERT:HARV	5	1.80687	0.361374	0.51933	0.7607780
Residuals	68	47.31758	0.695847		

WT/SO plots FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	22.04566	4.409132	12.32258	0.0000000
FERT	1	0.01945	0.019447	0.05435	0.8163576
HARV	1	0.07665	0.076648	0.21421	0.6449620
SITE:FERT	5	1.78269	0.356539	0.99645	0.4266241
SITE:HARV	5	0.59540	0.119079	0.33280	0.8914271
FERT:HARV	1	0.72373	0.723727	2.02266	0.1595381
SITE:FERT:HARV	5	0.63109	0.126218	0.35275	0.8787647
Residuals	68	24.33102	0.357809		

WT/SO plots FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	29.35241	5.870482	26.31800	0.0000000
FERT	1	0.16936	0.169356	0.75924	0.3866319
HARV	1	0.05463	0.054630	0.24491	0.6222767
SITE:FERT	5	3.21959	0.643918	2.88675	0.0201408
SITE:HARV	5	0.87742	0.175484	0.78672	0.5628439
FERT:HARV	1	0.24833	0.248331	1.11330	0.2951010
SITE:FERT:HARV	5	1.47099	0.294198	1.31892	0.2665332
Residuals	68	15.16805	0.223060		

WT/SO plots FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	35.29730	7.059459	11.59272	0.0000000
FERT	1	0.13407	0.134071	0.22016	0.6404155
HARV	1	0.02004	0.020042	0.03291	0.8565813
SITE:FERT	5	7.63032	1.526065	2.50603	0.0384024
SITE:HARV	5	1.28070	0.256140	0.42062	0.8328113
FERT:HARV	1	0.29840	0.298399	0.49002	0.4863080
SITE:FERT:HARV	5	1.95884	0.391768	0.64334	0.6674258
Residuals	68	41.40903	0.608956		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 continued

WT/SO plots FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	231.2396	46.24793	31.99548	0.0000000
FERT	1	0.0470	0.04704	0.03255	0.8573714
HARV	1	0.0183	0.01827	0.01264	0.9108181
SITE:FERT	5	13.1691	2.63381	1.82214	0.1201139
SITE:HARV	5	4.6741	0.93482	0.64673	0.6648874
FERT:HARV	1	3.5277	3.52769	2.44055	0.1228773
SITE:FERT:HARV	5	6.4003	1.28007	0.88558	0.4956813
Residuals	68	98.2907	1.44545		

WT/SO plots FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	57.21670	11.44334	28.46412	0.0000000
FERT	1	0.05209	0.05209	0.12956	0.7200062
HARV	1	0.04997	0.04997	0.12431	0.7254994
SITE:FERT	5	6.03208	1.20642	3.00083	0.0165932
SITE:HARV	5	1.29724	0.25945	0.64535	0.6659225
FERT:HARV	1	0.75076	0.75076	1.86743	0.1762714
SITE:FERT:HARV	5	3.69354	0.73871	1.83746	0.1171442
Residuals	68	27.33783	0.40203		

WT/SO plots Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	230.1138	46.02277	32.74371	0.0000000
FERT	1	0.6555	0.65550	0.46637	0.4969820
HARV	1	1.7267	1.72666	1.22846	0.2716109
SITE:FERT	5	13.6996	2.73992	1.94936	0.0974786
SITE:HARV	5	4.5694	0.91389	0.65020	0.6622912
FERT:HARV	1	0.4639	0.46388	0.33004	0.5675323
SITE:FERT:HARV	5	6.3525	1.27049	0.90391	0.4837845
Residuals	68	95.5771	1.40555		

WT/SO plots Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	416.0968	83.21936	31.12574	0.0000000
FERT	1	0.2037	0.20368	0.07618	0.7833810
HARV	1	0.0878	0.08776	0.03283	0.8567671
SITE:FERT	5	23.7912	4.75823	1.77968	0.1287185
SITE:HARV	5	4.2988	0.85976	0.32157	0.8983552
FERT:HARV	1	1.5803	1.58029	0.59106	0.4446715
SITE:FERT:HARV	5	30.0907	6.01814	2.25091	0.0590139
Residuals	68	181.8082	2.67365		

WT/SO plots Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2.362318	0.4724636	9.570717	0.0000006
FERT	1	0.004267	0.0042670	0.086436	0.7696536
HARV	1	0.085343	0.0853427	1.728791	0.1929825
SITE:FERT	5	0.373589	0.0747177	1.513560	0.1971574
SITE:HARV	5	0.311883	0.0623766	1.263567	0.2897940
FERT:HARV	1	0.027589	0.0275887	0.558866	0.4572950
SITE:FERT:HARV	5	0.085917	0.0171834	0.348084	0.8817663
Residuals	68	3.356857	0.0493655		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	12.74036	2.548073	13.87900	0.0000000
FERT	1	0.00899	0.008995	0.04899	0.8254881
HARV	1	0.06292	0.062923	0.34273	0.5601934
SITE:FERT	5	2.06833	0.413667	2.25318	0.0587891
SITE:HARV	5	0.42124	0.084248	0.45889	0.8054155
FERT:HARV	1	0.07605	0.076055	0.41426	0.5219805
SITE:FERT:HARV	5	1.53357	0.306713	1.67062	0.1535440
Residuals	68	12.48426	0.183592		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	44.37493	8.874987	58.08087	0.0000000
FERT	1	0.23889	0.238888	1.56336	0.2154595
HARV	1	0.41636	0.416365	2.72483	0.1034103
SITE:FERT	5	1.09859	0.219719	1.43791	0.2219417
SITE:HARV	5	0.86211	0.172421	1.12838	0.3538174
FERT:HARV	1	0.11154	0.111543	0.72997	0.3958920
SITE:FERT:HARV	5	0.68672	0.137345	0.89883	0.4870651
Residuals	68	10.39067	0.152804		

WT/SO plots Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	12.28720	2.457439	25.33703	0.0000000
FERT	1	0.06166	0.061661	0.63574	0.4280325
HARV	1	0.00146	0.001457	0.01503	0.9028030
SITE:FERT	5	0.50417	0.100834	1.03963	0.4016585
SITE:HARV	5	0.13691	0.027383	0.28233	0.9212610
FERT:HARV	1	0.10565	0.105648	1.08927	0.3003298
SITE:FERT:HARV	5	0.60361	0.120722	1.24468	0.2981123
Residuals	68	6.59532	0.096990		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 continued

WT/SO plots Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	6.823259	1.364652	18.29435	0.0000000
FERT	1	0.024922	0.024922	0.33410	0.5651643
HARV	1	0.000014	0.000014	0.00019	0.9890498
SITE:FERT	5	0.296196	0.059239	0.79415	0.5576269
SITE:HARV	5	0.169484	0.033897	0.45442	0.8086587
FERT:HARV	1	0.000013	0.000013	0.00018	0.9894083
SITE:FERT:HARV	5	0.167199	0.033440	0.44829	0.8130848
Residuals	68	5.072404	0.074594		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	17.02950	3.405899	16.05212	0.0000000
FERT	1	0.02534	0.025337	0.11942	0.7307358
HARV	1	0.11824	0.118240	0.55727	0.4579356
SITE:FERT	5	1.44172	0.288344	1.35898	0.2507201
SITE:HARV	5	0.15141	0.030282	0.14272	0.9815455
FERT:HARV	1	0.10280	0.102803	0.48451	0.4887576
SITE:FERT:HARV	5	1.38892	0.277784	1.30921	0.2704966
Residuals	68	14.42807	0.212178		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	88.68038	17.73608	41.23171	0.0000000
FERT	1	0.25724	0.25724	0.59802	0.4420154
HARV	1	0.41151	0.41151	0.95665	0.3314997
SITE:FERT	5	4.41988	0.88398	2.05501	0.0818404
SITE:HARV	5	1.73320	0.34664	0.80585	0.5494758
FERT:HARV	1	0.24594	0.24594	0.57174	0.4521811
SITE:FERT:HARV	5	6.92377	1.38475	3.21919	0.0114526
Residuals	68	29.25062	0.43016		

WT/SO plots Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	20.62214	4.124428	20.36533	0.0000000
FERT	1	0.06820	0.068204	0.33677	0.5636154
HARV	1	0.00003	0.000026	0.00013	0.9909175
SITE:FERT	5	1.70072	0.340143	1.67954	0.1513582
SITE:HARV	5	0.08945	0.017889	0.08833	0.9938443
FERT:HARV	1	0.19089	0.190889	0.94256	0.3350618
SITE:FERT:HARV	5	2.56519	0.513037	2.53324	0.0366759
Residuals	68	13.77150	0.202522		

4.2.2: WT and SO HARVESTING AT ALL SITES SUMMER 2003

WT/SO plots FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1728.501	345.7003	174.6935	0.0000000
FERT	1	1.619	1.6187	0.8180	0.3689655
HARV	1	0.018	0.0175	0.0089	0.9252935
SITE:FERT	5	11.895	2.3791	1.2022	0.3175464
SITE:HARV	5	37.881	7.5761	3.8285	0.0040878
FERT:HARV	1	2.429	2.4286	1.2273	0.2718414
SITE:FERT:HARV	5	6.685	1.3370	0.6756	0.6433462
Residuals	68	134.565	1.9789		

WT/SO plots FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1963.198	392.6396	138.9245	0.0000000
FERT	1	3.790	3.7895	1.3408	0.2509400
HARV	1	2.540	2.5402	0.8988	0.3464620
SITE:FERT	5	17.749	3.5498	1.2560	0.2931043
SITE:HARV	5	53.274	10.6548	3.7699	0.0045114
FERT:HARV	1	0.033	0.0329	0.0116	0.9143948
SITE:FERT:HARV	5	13.384	2.6767	0.9471	0.4565018
Residuals	68	192.187	2.8263		

WT/SO plots FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	40.11607	8.023213	112.4402	0.0000000
FERT	1	0.06888	0.068879	0.9653	0.3293378
HARV	1	0.00873	0.008730	0.1223	0.7275872
SITE:FERT	5	0.44654	0.089307	1.2516	0.2950490
SITE:HARV	5	2.03904	0.407808	5.7152	0.0001849
FERT:HARV	1	0.02401	0.024013	0.3365	0.5637590
SITE:FERT:HARV	5	0.28365	0.056731	0.7950	0.5570009
Residuals	68	4.85217	0.071355		

WT/SO plots FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	76.11857	15.22371	89.14381	0.0000000
FERT	1	0.17173	0.17173	1.00555	0.3195254
HARV	1	0.01449	0.01449	0.08482	0.7717500
SITE:FERT	5	0.66259	0.13252	0.77597	0.5704242
SITE:HARV	5	1.75610	0.35122	2.05660	0.0816243
FERT:HARV	1	0.21867	0.21867	1.28045	0.2617907
SITE:FERT:HARV	5	0.54752	0.10950	0.64122	0.6690213
Residuals	68	11.61284	0.17078		

WT and SO HARVESTING AT ALL SITES SUMMER 2003 continued

WT/SO plots FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	321.7897	64.35794	261.3839	0.0000000
FERT	1	0.0918	0.09178	0.3727	0.5435517
HARV	1	0.0002	0.00018	0.0007	0.9785305
SITE:FERT	5	1.0058	0.20115	0.8170	0.5417913
SITE:HARV	5	5.4433	1.08866	4.4215	0.0015172
FERT:HARV	1	0.0630	0.06296	0.2557	0.6147095
SITE:FERT:HARV	5	0.8121	0.16243	0.6597	0.6551984
Residuals	68	16.7430	0.24622		

WT/SO plots FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	80.33825	16.06765	124.5257	0.0000000
FERT	1	0.08555	0.08555	0.6630	0.4183420
HARV	1	0.12931	0.12931	1.0021	0.3203448
SITE:FERT	5	1.14723	0.22945	1.7782	0.1290212
SITE:HARV	5	1.49171	0.29834	2.3122	0.0532463
FERT:HARV	1	0.46909	0.46909	3.6355	0.0607865
SITE:FERT:HARV	5	0.70624	0.14125	1.0947	0.3714349
Residuals	68	8.77410	0.12903		

WT/SO plots FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	44.72084	8.944168	110.6029	0.0000000
FERT	1	0.16684	0.166845	2.0632	0.1554791
HARV	1	0.12752	0.127520	1.5769	0.2135045
SITE:FERT	5	0.68124	0.136247	1.6848	0.1500764
SITE:HARV	5	1.34817	0.269633	3.3343	0.0094217
FERT:HARV	1	0.00243	0.002429	0.0300	0.8629283
SITE:FERT:HARV	5	0.19268	0.038537	0.4765	0.7925178
Residuals	68	5.49898	0.080867		

WT/SO plots FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	86.00979	17.20196	85.54166	0.0000000
FERT	1	0.59888	0.59888	2.97810	0.0889400
HARV	1	0.17610	0.17610	0.87569	0.3526970
SITE:FERT	5	0.36560	0.07312	0.36361	0.8716915
SITE:HARV	5	2.95371	0.59074	2.93764	0.0184735
FERT:HARV	1	0.04572	0.04572	0.22734	0.6350334
SITE:FERT:HARV	5	0.19562	0.03912	0.19456	0.9636083
Residuals	68	13.67443	0.20109		

WT/SO plots FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	365.6602	73.13204	134.0175	0.0000000
FERT	1	0.5700	0.57002	1.0446	0.3103796
HARV	1	0.3514	0.35142	0.6440	0.4250627
SITE:FERT	5	3.8575	0.77149	1.4138	0.2304100
SITE:HARV	5	10.4576	2.09151	3.8328	0.0040582
FERT:HARV	1	0.0134	0.01337	0.0245	0.8761008
SITE:FERT:HARV	5	4.1858	0.83717	1.5341	0.1908602
Residuals	68	37.1069	0.54569		

WT/SO plots FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	90.25755	18.05151	106.3797	0.0000000
FERT	1	0.00009	0.00009	0.0005	0.9819817
HARV	1	0.05030	0.05030	0.2964	0.5879278
SITE:FERT	5	1.04900	0.20980	1.2364	0.3018349
SITE:HARV	5	1.89161	0.37832	2.2295	0.0611706
FERT:HARV	1	0.01755	0.01755	0.1034	0.7487564
SITE:FERT:HARV	5	1.23367	0.24673	1.4540	0.2164363
Residuals	68	11.53888	0.16969		

WT/SO plots Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	589.1949	117.8390	171.3029	0.0000000
FERT	1	0.2597	0.2597	0.3775	0.5409714
HARV	1	2.5172	2.5172	3.6592	0.0599718
SITE:FERT	5	2.2664	0.4533	0.6589	0.6557677
SITE:HARV	5	3.9666	0.7933	1.1532	0.3412503
FERT:HARV	1	1.2072	1.2072	1.7550	0.1896871
SITE:FERT:HARV	5	0.2957	0.0591	0.0860	0.9942217
Residuals	68	46.7771	0.6879		

WT/SO plots Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	394.7112	78.94224	81.29983	0.0000000
FERT	1	0.3647	0.36469	0.37558	0.5420231
HARV	1	7.4767	7.47667	7.69996	0.0071242
SITE:FERT	5	6.7088	1.34177	1.38184	0.2420661
SITE:HARV	5	14.4171	2.88341	2.96952	0.0174995
FERT:HARV	1	2.8426	2.84256	2.92745	0.0916432
SITE:FERT:HARV	5	1.0027	0.20055	0.20654	0.9586600
Residuals	68	66.0281	0.97100		

WT and SO HARVESTING AT ALL SITES SUMMER 2003 continued

WT/SO plots Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	12.56890	2.513780	120.6082	0.0000000
FERT	1	0.00023	0.000227	0.0109	0.9172540
HARV	1	0.00852	0.008521	0.4088	0.5247146
SITE:FERT	5	0.08732	0.017464	0.8379	0.5274518
SITE:HARV	5	0.09904	0.019809	0.9504	0.4544592
FERT:HARV	1	0.03556	0.035563	1.7063	0.1958702
SITE:FERT:HARV	5	0.16538	0.033077	1.5870	0.1755251
Residuals	68	1.41729	0.020843		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	34.69786	6.939572	90.01179	0.0000000
FERT	1	0.03423	0.034229	0.44397	0.5074663
HARV	1	0.28355	0.283545	3.67781	0.0593422
SITE:FERT	5	0.18600	0.037201	0.48252	0.7881175
SITE:HARV	5	0.41608	0.083215	1.07937	0.3796593
FERT:HARV	1	0.16184	0.161843	2.09924	0.1519686
SITE:FERT:HARV	5	0.24008	0.048017	0.62282	0.6828421
Residuals	68	5.24255	0.077096		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	87.18711	17.43742	150.8286	0.0000000
FERT	1	0.03721	0.03721	0.3218	0.5723690
HARV	1	0.15252	0.15252	1.3192	0.2547527
SITE:FERT	5	0.13109	0.02622	0.2268	0.9496633
SITE:HARV	5	0.45422	0.09084	0.7858	0.5635107
FERT:HARV	1	0.04485	0.04485	0.3879	0.5354765
SITE:FERT:HARV	5	0.04218	0.00844	0.0730	0.9960706
Residuals	68	7.86154	0.11561		

WT/SO plots Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	32.01154	6.402308	168.0802	0.0000000
FERT	1	0.01361	0.013609	0.3573	0.5520036
HARV	1	0.32630	0.326297	8.5663	0.0046529
SITE:FERT	5	0.42358	0.084717	2.2241	0.0617286
SITE:HARV	5	0.24628	0.049257	1.2931	0.2771610
FERT:HARV	1	0.08767	0.087672	2.3016	0.1338722
SITE:FERT:HARV	5	0.04146	0.008293	0.2177	0.9537920
Residuals	68	2.59017	0.038091		

WT/SO plots Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	10.65388	2.130776	85.66900	0.0000000
FERT	1	0.01260	0.012603	0.50673	0.4789938
HARV	1	0.18417	0.184173	7.40476	0.0082535
SITE:FERT	5	0.19854	0.039707	1.59646	0.1728962
SITE:HARV	5	0.15151	0.030301	1.21828	0.3100806
FERT:HARV	1	0.20265	0.202654	8.14781	0.0057100
SITE:FERT:HARV	5	0.26353	0.052706	2.11908	0.0735661
Residuals	68	1.69131	0.024872		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	20.21873	4.043746	57.97738	0.0000000
FERT	1	0.00165	0.001650	0.02366	0.8782040
HARV	1	0.30849	0.308487	4.42295	0.0391619
SITE:FERT	5	0.55520	0.111041	1.59205	0.1741125
SITE:HARV	5	0.84171	0.168342	2.41361	0.0448873
FERT:HARV	1	0.22464	0.224643	3.22082	0.0771515
SITE:FERT:HARV	5	0.12234	0.024469	0.35082	0.8800096
Residuals	68	4.74279	0.069747		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	68.65090	13.73018	53.56342	0.0000000
FERT	1	0.50887	0.50887	1.98519	0.1634016
HARV	1	0.55357	0.55357	2.15955	0.1462977
SITE:FERT	5	1.05892	0.21178	0.82620	0.5354392
SITE:HARV	5	2.99864	0.59973	2.33963	0.0508437
FERT:HARV	1	0.12596	0.12596	0.49139	0.4857014
SITE:FERT:HARV	5	0.33380	0.06676	0.26044	0.9330624
Residuals	68	17.43078	0.25634		

WT/SO plots Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	16.83136	3.366272	55.24607	0.0000000
FERT	1	0.00143	0.001430	0.02347	0.8786869
HARV	1	1.01155	1.011550	16.60120	0.0001229
SITE:FERT	5	0.49401	0.098803	1.62152	0.1661185
SITE:HARV	5	0.83910	0.167821	2.75421	0.0252225
FERT:HARV	1	0.16561	0.165605	2.71786	0.1038441
SITE:FERT:HARV	5	0.22332	0.044664	0.73301	0.6012045
Residuals	68	4.14340	0.060932		

4.2.3: WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003

WT/SO plots FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	1728.514	345.7029	91.36203	0.0000000
YEAR	1	194.904	194.9036	51.50895	0.0000000
FERT	1	0.003	0.0035	0.00092	0.9758366
HARV	1	0.350	0.3505	0.09263	0.7613256
SITE:YEAR	5	396.106	79.2212	20.93651	0.0000000
SITE:FERT	5	16.154	3.2307	0.85381	0.5140845
YEAR:FERT	1	3.028	3.0285	0.80036	0.3725673
SITE:HARV	5	8.906	1.7812	0.47074	0.7975417
YEAR:HARV	1	0.164	0.1639	0.04330	0.8354651
FERT:HARV	1	12.480	12.4798	3.29815	0.0715604
SITE:YEAR:FERT	5	33.124	6.6249	1.75081	0.1271939
SITE:YEAR:HARV	5	44.603	8.9206	2.35753	0.0435275
SITE:FERT:HARV	5	9.107	1.8213	0.48134	0.7897133
YEAR:FERT:HARV	1	1.766	1.7656	0.46661	0.4957146
SITE:YEAR:FERT:HARV	5	3.043	0.6085	0.16082	0.9763576
Residuals	136	514.608	3.7839		

WT/SO plots FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	2465.429	493.086	92.1307	0.0000000
YEAR	1	1410.091	1410.091	263.4687	0.0000000
FERT	1	2.970	2.970	0.5549	0.4575949
HARV	1	1.276	1.276	0.2384	0.6261306
SITE:YEAR	5	610.663	122.133	22.8199	0.0000000
SITE:FERT	5	45.930	9.186	1.7164	0.1349015
YEAR:FERT	1	1.060	1.060	0.1981	0.6569776
SITE:HARV	5	28.132	5.626	1.0513	0.3903541
YEAR:HARV	1	1.264	1.264	0.2362	0.6277402
FERT:HARV	1	7.883	7.883	1.4729	0.2269845
SITE:YEAR:FERT	5	80.965	16.193	3.0256	0.0127253
SITE:YEAR:HARV	5	42.714	8.543	1.5962	0.1652578
SITE:FERT:HARV	5	16.381	3.276	0.6121	0.6907550
YEAR:FERT:HARV	1	6.509	6.509	1.2161	0.2720765
SITE:YEAR:FERT:HARV	5	31.441	6.288	1.1749	0.3247113
Residuals	136	727.875	5.352		

WT/SO plots FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	47.02724	9.405448	72.14697	0.0000000
YEAR	1	9.27649	9.276493	71.15779	0.0000000
FERT	1	0.07270	0.072700	0.55766	0.4564931
HARV	1	0.00489	0.004885	0.03747	0.8467903
SITE:YEAR	5	6.73007	1.346015	10.32496	0.0000000
SITE:FERT	5	0.66996	0.133991	1.02782	0.4038476
YEAR:FERT	1	0.01031	0.010308	0.07907	0.7789848
SITE:HARV	5	0.22338	0.044676	0.34270	0.8861850
YEAR:HARV	1	0.04082	0.040817	0.31309	0.5767077
FERT:HARV	1	0.31150	0.311496	2.38941	0.1244832
SITE:YEAR:FERT	5	0.89338	0.178677	1.37059	0.2391907
SITE:YEAR:HARV	5	2.67258	0.534516	4.10014	0.0016881
SITE:FERT:HARV	5	0.42675	0.085350	0.65470	0.6584124
YEAR:FERT:HARV	1	0.11490	0.114901	0.88138	0.3494886
SITE:YEAR:FERT:HARV	5	0.27031	0.054062	0.41470	0.8379099
Residuals	136	17.72966	0.130365		

WT/SO plots FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	83.82692	16.76538	57.17385	0.0000000
YEAR	1	18.58213	18.58213	63.36936	0.0000000
FERT	1	0.00003	0.00003	0.00009	0.9922409
HARV	1	0.01355	0.01355	0.04621	0.8301079
SITE:YEAR	5	17.05713	3.41143	11.63375	0.0000000
SITE:FERT	5	1.74159	0.34832	1.18785	0.3183908
YEAR:FERT	1	0.34966	0.34966	1.19243	0.2767705
SITE:HARV	5	0.54698	0.10940	0.37307	0.8664254
YEAR:HARV	1	0.00289	0.00289	0.00987	0.9210064
FERT:HARV	1	0.94699	0.94699	3.22945	0.0745439
SITE:YEAR:FERT	5	3.31455	0.66291	2.26068	0.0518455
SITE:YEAR:HARV	5	2.51509	0.50302	1.71541	0.1351225
SITE:FERT:HARV	5	0.58525	0.11705	0.39917	0.8487204
YEAR:FERT:HARV	1	0.09723	0.09723	0.33157	0.5656858
SITE:YEAR:FERT:HARV	5	0.15809	0.03162	0.10782	0.9904250
Residuals	136	39.87998	0.29324		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT/SO plots FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	278.5918	55.71835	118.2896	0.0000000
YEAR	1	7.3089	7.30888	15.5167	0.0001301
FERT	1	0.0982	0.09824	0.2086	0.6486271
HARV	1	0.0356	0.03558	0.0755	0.7838674
SITE:YEAR	5	89.9784	17.99568	38.2047	0.0000000
SITE:FERT	5	1.2455	0.24909	0.5288	0.7541438
YEAR:FERT	1	0.5504	0.55035	1.1684	0.2816442
SITE:HARV	5	1.5710	0.31420	0.6670	0.6490828
YEAR:HARV	1	0.0431	0.04309	0.0915	0.7627765
FERT:HARV	1	0.8385	0.83847	1.7801	0.1843703
SITE:YEAR:FERT	5	2.8306	0.56611	1.2019	0.3116448
SITE:YEAR:HARV	5	6.0059	1.20118	2.5501	0.0306503
SITE:FERT:HARV	5	2.0631	0.41262	0.8760	0.4990845
YEAR:FERT:HARV	1	0.3145	0.31452	0.6677	0.4152778
SITE:YEAR:FERT:HARV	5	0.5559	0.11118	0.2360	0.9460248
Residuals	136	64.0605	0.47103		

WT/SO plots FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	82.17485	16.43497	67.51693	0.0000000
YEAR	1	15.21756	15.21756	62.51566	0.0000000
FERT	1	0.01171	0.01171	0.04810	0.8267245
HARV	1	0.20253	0.20253	0.83202	0.3633027
SITE:YEAR	5	20.20906	4.04181	16.60427	0.0000000
SITE:FERT	5	0.89924	0.17985	0.73884	0.5956186
YEAR:FERT	1	0.09329	0.09329	0.38323	0.5369137
SITE:HARV	5	0.59659	0.11932	0.49017	0.7831548
YEAR:HARV	1	0.00342	0.00342	0.01406	0.9057835
FERT:HARV	1	1.17907	1.17907	4.84376	0.0294334
SITE:YEAR:FERT	5	2.03068	0.40614	1.66846	0.1463341
SITE:YEAR:HARV	5	1.49051	0.29810	1.22464	0.3009122
SITE:FERT:HARV	5	1.07835	0.21567	0.88600	0.4924037
YEAR:FERT:HARV	1	0.01375	0.01375	0.05648	0.8125063
SITE:YEAR:FERT:HARV	5	0.25897	0.05179	0.21278	0.9566054
Residuals	136	33.10512	0.24342		

WT/SO plots FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	62.78199	12.55640	82.6277	0.0000000
YEAR	1	29.99850	29.99850	197.4060	0.0000000
FERT	1	0.33620	0.33620	2.2123	0.1392250
HARV	1	0.17454	0.17454	1.1486	0.2857478
SITE:YEAR	5	11.29126	2.25825	14.8605	0.0000000
SITE:FERT	5	2.19455	0.43891	2.8883	0.0164276
YEAR:FERT	1	0.00000	0.00000	0.0000	0.9955752
SITE:HARV	5	0.48407	0.09681	0.6371	0.6717605
YEAR:HARV	1	0.00761	0.00761	0.0501	0.8232631
FERT:HARV	1	0.10082	0.10082	0.6635	0.4167661
SITE:YEAR:FERT	5	1.70627	0.34125	2.2456	0.0532677
SITE:YEAR:HARV	5	1.74152	0.34830	2.2920	0.0489990
SITE:FERT:HARV	5	0.94985	0.18997	1.2501	0.2892795
YEAR:FERT:HARV	1	0.14994	0.14994	0.9867	0.3223198
SITE:YEAR:FERT:HARV	5	0.71382	0.14276	0.9395	0.4576485
Residuals	136	20.66703	0.15196		

WT/SO plots FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	93.42482	18.68496	46.13282	0.0000000
YEAR	1	37.02438	37.02438	91.41248	0.0000000
FERT	1	0.08312	0.08312	0.20521	0.6512676
HARV	1	0.03866	0.03866	0.09545	0.7578276
SITE:YEAR	5	27.88227	5.57645	13.76816	0.0000000
SITE:FERT	5	3.10848	0.62170	1.53496	0.1829895
YEAR:FERT	1	0.64983	0.64983	1.60443	0.2074419
SITE:HARV	5	0.63720	0.12744	0.31465	0.9034935
YEAR:HARV	1	0.15748	0.15748	0.38881	0.5339720
FERT:HARV	1	0.28886	0.28886	0.71318	0.3998738
SITE:YEAR:FERT	5	4.88744	0.97749	2.41340	0.0393310
SITE:YEAR:HARV	5	3.59721	0.71944	1.77629	0.1217564
SITE:FERT:HARV	5	0.94925	0.18985	0.46874	0.7990148
YEAR:FERT:HARV	1	0.05526	0.05526	0.13644	0.7124253
SITE:YEAR:FERT:HARV	5	1.20521	0.24104	0.59513	0.7037120
Residuals	136	55.08345	0.40503		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT/SO plots FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	472.8881	94.5776	94.9984	0.0000000
YEAR	1	281.3932	281.3932	282.6450	0.0000000
FERT	1	0.4723	0.4723	0.4744	0.4921485
HARV	1	0.2650	0.2650	0.2662	0.6067625
SITE:YEAR	5	124.0117	24.8023	24.9127	0.0000000
SITE:FERT	5	4.8599	0.9720	0.9763	0.4346490
YEAR:FERT	1	0.1448	0.1448	0.1454	0.7035454
SITE:HARV	5	7.6679	1.5336	1.5404	0.1813446
YEAR:HARV	1	0.1047	0.1047	0.1052	0.7461918
FERT:HARV	1	1.5534	1.5534	1.5603	0.2137670
SITE:YEAR:FERT	5	12.1666	2.4333	2.4441	0.0371918
SITE:YEAR:HARV	5	7.4637	1.4927	1.4994	0.1940528
SITE:FERT:HARV	5	5.1298	1.0260	1.0305	0.4022676
YEAR:FERT:HARV	1	1.9877	1.9877	1.9965	0.1599462
SITE:YEAR:FERT:HARV	5	5.4563	1.0913	1.0961	0.3654737
Residuals	136	135.3977	0.9956		

WT/SO plots FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	118.5867	23.71734	82.9689	0.0000000
YEAR	1	84.9071	84.90713	297.0254	0.0000000
FERT	1	0.0282	0.02822	0.0987	0.7538625
HARV	1	0.0000	0.00000	0.0000	0.9992441
SITE:YEAR	5	28.8876	5.77751	20.2111	0.0000000
SITE:FERT	5	2.4428	0.48856	1.7091	0.1365834
YEAR:FERT	1	0.0240	0.02396	0.0838	0.7726507
SITE:HARV	5	2.2521	0.45041	1.5757	0.1710260
YEAR:HARV	1	0.1003	0.10027	0.3508	0.5546600
FERT:HARV	1	0.4989	0.49893	1.7454	0.1886762
SITE:YEAR:FERT	5	4.6383	0.92766	3.2452	0.0084427
SITE:YEAR:HARV	5	0.9368	0.18736	0.6554	0.6578654
SITE:FERT:HARV	5	1.5703	0.31407	1.0987	0.3640931
YEAR:FERT:HARV	1	0.2694	0.26937	0.9423	0.3334031
SITE:YEAR:FERT:HARV	5	3.3569	0.67138	2.3486	0.0442337
Residuals	136	38.8767	0.28586		

WT/SO plots Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	429.0260	85.8052	81.9752	0.0000000
YEAR	1	167.9070	167.9070	160.4123	0.0000000
FERT	1	0.8702	0.8702	0.8314	0.3634904
HARV	1	4.2067	4.2067	4.0189	0.0469777
SITE:YEAR	5	390.2827	78.0565	74.5724	0.0000000
SITE:FERT	5	10.2886	2.0577	1.9659	0.0875915
YEAR:FERT	1	0.0450	0.0450	0.0430	0.8360445
SITE:HARV	5	3.7877	0.7575	0.7237	0.6067491
YEAR:HARV	1	0.0371	0.0371	0.0355	0.8508745
FERT:HARV	1	0.0872	0.0872	0.0833	0.7732798
SITE:YEAR:FERT	5	5.6774	1.1355	1.0848	0.3716404
SITE:YEAR:HARV	5	4.7484	0.9497	0.9073	0.4783771
SITE:FERT:HARV	5	2.6731	0.5346	0.5108	0.7677605
YEAR:FERT:HARV	1	1.5839	1.5839	1.5132	0.2207734
SITE:YEAR:FERT:HARV	5	3.9751	0.7950	0.7595	0.5805265
Residuals	136	142.3542	1.0467		

WT/SO plots Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	486.3735	97.2747	53.3794	0.0000000
YEAR	1	386.3991	386.3991	212.0362	0.0000000
FERT	1	0.5567	0.5567	0.3055	0.5813616
HARV	1	4.5923	4.5923	2.5200	0.1147327
SITE:YEAR	5	324.4345	64.8869	35.6066	0.0000000
SITE:FERT	5	25.8199	5.1640	2.8337	0.0181756
YEAR:FERT	1	0.0116	0.0116	0.0064	0.9364126
SITE:HARV	5	13.7986	2.7597	1.5144	0.1893142
YEAR:HARV	1	2.9722	2.9722	1.6310	0.2037443
FERT:HARV	1	0.0920	0.0920	0.0505	0.8225822
SITE:YEAR:FERT	5	4.6801	0.9360	0.5136	0.7655936
SITE:YEAR:HARV	5	4.9172	0.9834	0.5397	0.7459347
SITE:FERT:HARV	5	11.7034	2.3407	1.2844	0.2741824
YEAR:FERT:HARV	1	4.3309	4.3309	2.3766	0.1254917
SITE:YEAR:FERT:HARV	5	19.3901	3.8780	2.1281	0.0657452
Residuals	136	247.8363	1.8223		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT/SO plots Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	7.877671	1.575534	44.8819	0.0000000
YEAR	1	5.449249	5.449249	155.2314	0.0000000
FERT	1	0.003230	0.003230	0.0920	0.7620903
HARV	1	0.073898	0.073898	2.1051	0.1491087
SITE:YEAR	5	7.053545	1.410709	40.1865	0.0000000
SITE:FERT	5	0.158676	0.031735	0.9040	0.4805018
YEAR:FERT	1	0.001263	0.001263	0.0360	0.8498193
SITE:HARV	5	0.245149	0.049030	1.3967	0.2293652
YEAR:HARV	1	0.019965	0.019965	0.5687	0.4520628
FERT:HARV	1	0.062899	0.062899	1.7918	0.1829414
SITE:YEAR:FERT	5	0.302234	0.060447	1.7219	0.1336272
SITE:YEAR:HARV	5	0.165777	0.033155	0.9445	0.4544640
SITE:FERT:HARV	5	0.127631	0.025526	0.7272	0.6042088
YEAR:FERT:HARV	1	0.000253	0.000253	0.0072	0.9325027
SITE:YEAR:FERT:HARV	5	0.123669	0.024734	0.7046	0.6209400
Residuals	136	4.774148	0.035104		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	26.97670	5.39534	41.39305	0.0000000
YEAR	1	12.51261	12.51261	95.99670	0.0000000
FERT	1	0.03916	0.03916	0.30042	0.5845175
HARV	1	0.30681	0.30681	2.35382	0.1272995
SITE:YEAR	5	20.46152	4.09230	31.39615	0.0000000
SITE:FERT	5	1.46015	0.29203	2.24046	0.0537655
YEAR:FERT	1	0.00407	0.00407	0.03119	0.8600836
SITE:HARV	5	0.42792	0.08558	0.65660	0.6569726
YEAR:HARV	1	0.03966	0.03966	0.30429	0.5821131
FERT:HARV	1	0.00800	0.00800	0.06140	0.8046680
SITE:YEAR:FERT	5	0.79418	0.15884	1.21860	0.3037301
SITE:YEAR:HARV	5	0.40940	0.08188	0.62818	0.6785350
SITE:FERT:HARV	5	1.10494	0.22099	1.69542	0.1397970
YEAR:FERT:HARV	1	0.22989	0.22989	1.76375	0.1863818
SITE:YEAR:FERT:HARV	5	0.66871	0.13374	1.02607	0.4048637
Residuals	136	17.72680	0.13034		

WT/SO plots Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	66.81217	13.36243	99.5655	0.0000000
YEAR	1	15.90919	15.90919	118.5418	0.0000000
FERT	1	0.23233	0.23233	1.7311	0.1904824
HARV	1	0.53644	0.53644	3.9971	0.0475713
SITE:YEAR	5	64.74987	12.94997	96.4922	0.0000000
SITE:FERT	5	0.87201	0.17440	1.2995	0.2677767
YEAR:FERT	1	0.04377	0.04377	0.3261	0.5688932
SITE:HARV	5	0.69723	0.13945	1.0390	0.3973529
YEAR:HARV	1	0.03244	0.03244	0.2417	0.6237469
FERT:HARV	1	0.00747	0.00747	0.0556	0.8138807
SITE:YEAR:FERT	5	0.35768	0.07154	0.5330	0.7509666
SITE:YEAR:HARV	5	0.61910	0.12382	0.9226	0.4684406
SITE:FERT:HARV	5	0.27709	0.05542	0.4129	0.8391530
YEAR:FERT:HARV	1	0.14892	0.14892	1.1097	0.2940253
SITE:YEAR:FERT:HARV	5	0.45181	0.09036	0.6733	0.6443646
Residuals	136	18.25221	0.13421		

WT/SO plots Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	23.66029	4.732058	70.0626	0.0000000
YEAR	1	9.21508	9.215081	136.4380	0.0000000
FERT	1	0.06660	0.066603	0.9861	0.3224555
HARV	1	0.18568	0.185684	2.7492	0.0996066
SITE:YEAR	5	20.63845	4.127690	61.1144	0.0000000
SITE:FERT	5	0.69237	0.138474	2.0502	0.0754873
YEAR:FERT	1	0.00867	0.008667	0.1283	0.7207362
SITE:HARV	5	0.02247	0.004493	0.0665	0.9969138
YEAR:HARV	1	0.14207	0.142071	2.1035	0.1492653
FERT:HARV	1	0.00042	0.000419	0.0062	0.9373509
SITE:YEAR:FERT	5	0.23538	0.047076	0.6970	0.6265907
SITE:YEAR:HARV	5	0.36073	0.072146	1.0682	0.3808192
SITE:FERT:HARV	5	0.24614	0.049228	0.7289	0.6029521
YEAR:FERT:HARV	1	0.19290	0.192901	2.8561	0.0933200
SITE:YEAR:FERT:HARV	5	0.39893	0.079787	1.1813	0.3215734
Residuals	136	9.18550	0.067540		

WT and SO HARVESTING AT ALL SITES SUMMER 2002 and 2003 continued

WT/SO plots Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	11.17010	2.234021	44.92012	0.0000000
YEAR	1	3.59062	3.590618	72.19763	0.0000000
FERT	1	0.03649	0.036486	0.73363	0.3932169
HARV	1	0.09371	0.093708	1.88421	0.1721154
SITE:YEAR	5	6.30704	1.261407	25.36349	0.0000000
SITE:FERT	5	0.14286	0.028573	0.57452	0.7194283
YEAR:FERT	1	0.00104	0.001040	0.02091	0.8852476
SITE:HARV	5	0.28407	0.056814	1.14237	0.3411002
YEAR:HARV	1	0.09048	0.090479	1.81928	0.1796401
FERT:HARV	1	0.09970	0.099695	2.00460	0.1591083
SITE:YEAR:FERT	5	0.35187	0.070374	1.41503	0.2226794
SITE:YEAR:HARV	5	0.03692	0.007384	0.14848	0.9802020
SITE:FERT:HARV	5	0.15039	0.030078	0.60479	0.6963431
YEAR:FERT:HARV	1	0.10297	0.102972	2.07048	0.1524714
SITE:YEAR:FERT:HARV	5	0.28034	0.056068	1.12737	0.3488646
Residuals	136	6.76371	0.049733		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	23.57629	4.71526	33.45051	0.0000000
YEAR	1	13.49582	13.49582	95.74066	0.0000000
FERT	1	0.00703	0.00703	0.04985	0.8236546
HARV	1	0.02238	0.02238	0.15875	0.6909339
SITE:YEAR	5	13.67193	2.73439	19.39801	0.0000000
SITE:FERT	5	1.65463	0.33093	2.34762	0.0443156
YEAR:FERT	1	0.01996	0.01996	0.14160	0.7072815
SITE:HARV	5	0.80983	0.16197	1.14900	0.3377108
YEAR:HARV	1	0.40435	0.40435	2.86849	0.0926185
FERT:HARV	1	0.01176	0.01176	0.08340	0.7731838
SITE:YEAR:FERT	5	0.34230	0.06846	0.48566	0.7865085
SITE:YEAR:HARV	5	0.18329	0.03666	0.26005	0.9340755
SITE:FERT:HARV	5	0.68484	0.13697	0.97166	0.4375055
YEAR:FERT:HARV	1	0.31569	0.31569	2.23953	0.1368388
SITE:YEAR:FERT:HARV	5	0.82643	0.16529	1.17255	0.3258918
Residuals	136	19.17086	0.14096		

WT/SO plots Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	87.68641	17.53728	51.0925	0.0000000
YEAR	1	92.64084	92.64084	269.8966	0.0000000
FERT	1	0.74486	0.74486	2.1701	0.1430318
HARV	1	0.95982	0.95982	2.7963	0.0967807
SITE:YEAR	5	69.64487	13.92897	40.5802	0.0000000
SITE:FERT	5	4.76505	0.95301	2.7765	0.0202076
YEAR:FERT	1	0.02125	0.02125	0.0619	0.8038709
SITE:HARV	5	3.23317	0.64663	1.8839	0.1010877
YEAR:HARV	1	0.00526	0.00526	0.0153	0.9016959
FERT:HARV	1	0.00994	0.00994	0.0290	0.8651125
SITE:YEAR:FERT	5	0.71375	0.14275	0.4159	0.8370773
SITE:YEAR:HARV	5	1.49868	0.29974	0.8732	0.5009341
SITE:FERT:HARV	5	3.49907	0.69981	2.0388	0.0770282
YEAR:FERT:HARV	1	0.36195	0.36195	1.0545	0.3062952
SITE:YEAR:FERT:HARV	5	3.75850	0.75170	2.1900	0.0588616
Residuals	136	46.68140	0.34325		

WT/SO plots Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	5	23.58298	4.71660	35.8058	0.0000000
YEAR	1	19.92256	19.92256	151.2411	0.0000000
FERT	1	0.02494	0.02494	0.1893	0.6641611
HARV	1	0.50062	0.50062	3.8004	0.0532979
SITE:YEAR	5	13.87052	2.77410	21.0595	0.0000000
SITE:FERT	5	1.84445	0.36889	2.8004	0.0193325
YEAR:FERT	1	0.04469	0.04469	0.3393	0.5612026
SITE:HARV	5	0.43780	0.08756	0.6647	0.6508468
YEAR:HARV	1	0.51096	0.51096	3.8789	0.0509282
FERT:HARV	1	0.00045	0.00045	0.0034	0.9535372
SITE:YEAR:FERT	5	0.35028	0.07006	0.5318	0.7518661
SITE:YEAR:HARV	5	0.49075	0.09815	0.7451	0.5910348
SITE:FERT:HARV	5	0.99116	0.19823	1.5049	0.1923108
YEAR:FERT:HARV	1	0.35605	0.35605	2.7029	0.1024757
SITE:YEAR:FERT:HARV	5	1.79735	0.35947	2.7289	0.0220636
Residuals	136	17.91490	0.13173		

4.3.1: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002

All OMR sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	171.6117	57.20389	12.00803	0.0000023
FERT	1	3.6474	3.64741	0.76565	0.3847394
HARV	2	12.9285	6.46426	1.35695	0.2645311
SITE:FERT	3	5.3347	1.77823	0.37328	0.7725395
SITE:HARV	6	23.8124	3.96874	0.83310	0.5486880
FERT:HARV	2	13.2534	6.62671	1.39105	0.2560110
SITE:FERT:HARV	6	9.7932	1.63219	0.34262	0.9117208
Residuals	66	314.4111	4.76380		

All OMR sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1166.137	388.7123	46.01856	0.0000000
FERT	1	33.746	33.7457	3.99506	0.0497554
HARV	2	34.590	17.2950	2.04750	0.1371757
SITE:FERT	3	5.865	1.9550	0.23145	0.8741637
SITE:HARV	6	39.589	6.5981	0.78113	0.5877127
FERT:HARV	2	9.152	4.5760	0.54174	0.5843017
SITE:FERT:HARV	6	50.890	8.4816	1.00412	0.4302722
Residuals	66	557.493	8.4469		

All OMR sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3.65911	1.219704	7.415376	0.0002356
FERT	1	0.31243	0.312431	1.899470	0.1727921
HARV	2	0.74361	0.371807	2.260457	0.1123203
SITE:FERT	3	0.08015	0.026716	0.162423	0.9212728
SITE:HARV	6	1.17181	0.195301	1.187363	0.3239533
FERT:HARV	2	0.21569	0.107843	0.655648	0.5224534
SITE:FERT:HARV	6	0.55894	0.093156	0.566358	0.7555640
Residuals	66	10.85589	0.164483		

All OMR sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	9.09021	3.030070	8.731035	0.0000587
FERT	1	0.33977	0.339766	0.979023	0.3260538
HARV	2	0.94400	0.472002	1.360057	0.2637438
SITE:FERT	3	1.43467	0.478224	1.377986	0.2572104
SITE:HARV	6	2.68190	0.446984	1.287968	0.2749987
FERT:HARV	2	0.82710	0.413550	1.191630	0.3101748
SITE:FERT:HARV	6	0.90196	0.150327	0.433160	0.8541854
Residuals	66	22.90503	0.347046		

All OMR sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	24.79164	8.263879	14.36372	0.0000003
FERT	1	0.04915	0.049150	0.08543	0.7709868
HARV	2	0.56660	0.283300	0.49241	0.6133771
SITE:FERT	3	0.40894	0.136314	0.23693	0.8703036
SITE:HARV	6	1.92219	0.320365	0.55684	0.7629409
FERT:HARV	2	1.83919	0.919597	1.59838	0.2099514
SITE:FERT:HARV	6	1.81063	0.301772	0.52452	0.7877066
Residuals	66	37.97178	0.575330		

All OMR sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	11.50476	3.834918	12.52864	0.0000014
FERT	1	0.29858	0.298576	0.97545	0.3269326
HARV	2	1.28740	0.643698	2.10296	0.1302021
SITE:FERT	3	0.12092	0.040307	0.13168	0.9408955
SITE:HARV	6	1.53240	0.255401	0.83439	0.5477355
FERT:HARV	2	0.91300	0.456500	1.49138	0.2325472
SITE:FERT:HARV	6	0.58400	0.097333	0.31799	0.9253854
Residuals	66	20.20208	0.306092		

All OMR sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	30.28586	10.09529	46.36252	0.0000000
FERT	1	1.51364	1.51364	6.95138	0.0104315
HARV	2	0.99692	0.49846	2.28918	0.1093427
SITE:FERT	3	0.15944	0.05315	0.24408	0.8652566
SITE:HARV	6	1.14326	0.19054	0.87507	0.5180966
FERT:HARV	2	0.05501	0.02751	0.12632	0.8815427
SITE:FERT:HARV	6	0.52591	0.08765	0.40254	0.8747862
Residuals	66	14.37128	0.21775		

All OMR sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	48.51191	16.17064	27.83628	0.0000000
FERT	1	1.38239	1.38239	2.37966	0.1277057
HARV	2	1.53430	0.76715	1.32058	0.2739413
SITE:FERT	3	0.44927	0.14976	0.25779	0.8555182
SITE:HARV	6	1.33431	0.22238	0.38281	0.8874759
FERT:HARV	2	0.09289	0.04645	0.07995	0.9232472
SITE:FERT:HARV	6	2.57210	0.42868	0.73794	0.6209278
Residuals	66	38.34069	0.58092		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 continued

All OMR sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	180.1834	60.06113	37.19558	0.0000000
FERT	1	4.1645	4.16447	2.57904	0.1130618
HARV	2	3.9045	1.95227	1.20903	0.3050095
SITE:FERT	3	1.6522	0.55072	0.34106	0.7956948
SITE:HARV	6	11.8558	1.97597	1.22371	0.3055123
FERT:HARV	2	4.2638	2.13192	1.32029	0.2740187
SITE:FERT:HARV	6	13.1929	2.19882	1.36172	0.2431516
Residuals	66	106.5727	1.61474		

All OMR sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	71.59722	23.86574	50.23045	0.0000000
FERT	1	1.85585	1.85585	3.90603	0.0522947
HARV	2	3.33611	1.66805	3.51077	0.0355686
SITE:FERT	3	0.12819	0.04273	0.08993	0.9653382
SITE:HARV	6	1.99532	0.33255	0.69993	0.6505903
FERT:HARV	2	0.74338	0.37169	0.78230	0.4615466
SITE:FERT:HARV	6	3.81898	0.63650	1.33964	0.2523405
Residuals	66	31.35825	0.47512		

All OMR sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	231.4339	77.14464	66.13084	0.0000000
FERT	1	0.1200	0.12005	0.10291	0.7493789
HARV	2	3.8625	1.93123	1.65551	0.1988259
SITE:FERT	3	6.2266	2.07553	1.77921	0.1596850
SITE:HARV	6	13.6563	2.27605	1.95111	0.0854604
FERT:HARV	2	0.9216	0.46082	0.39503	0.6752428
SITE:FERT:HARV	6	5.6597	0.94329	0.80862	0.5669302
Residuals	66	76.9920	1.16655		

All OMR sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	479.3086	159.7695	66.49503	0.0000000
FERT	1	0.0704	0.0704	0.02932	0.8645643
HARV	2	6.9342	3.4671	1.44298	0.2435767
SITE:FERT	3	23.7426	7.9142	3.29384	0.0258290
SITE:HARV	6	16.6177	2.7696	1.15269	0.3423535
FERT:HARV	2	4.2166	2.1083	0.87746	0.4206330
SITE:FERT:HARV	6	26.8841	4.4807	1.86483	0.1000994
Residuals	66	158.5801	2.4027		

All OMR sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.628079	0.5426930	11.86177	0.0000026
FERT	1	0.000875	0.0008753	0.01913	0.8904116
HARV	2	0.215624	0.1078118	2.35647	0.1026804
SITE:FERT	3	0.099487	0.0331623	0.72484	0.5407638
SITE:HARV	6	0.483674	0.0806124	1.76196	0.1206493
FERT:HARV	2	0.027496	0.0137481	0.30050	0.7414582
SITE:FERT:HARV	6	0.083019	0.0138366	0.30243	0.9335002
Residuals	66	3.019595	0.0457514		

All OMR sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	10.27294	3.424312	23.89393	0.0000000
FERT	1	0.05876	0.058762	0.41003	0.5241729
HARV	2	0.14523	0.072617	0.50670	0.6048057
SITE:FERT	3	0.91957	0.306523	2.13883	0.1036631
SITE:HARV	6	1.35782	0.226304	1.57909	0.1671626
FERT:HARV	2	0.48230	0.241151	1.68269	0.1937493
SITE:FERT:HARV	6	1.22639	0.204399	1.42624	0.2179341
Residuals	66	9.45866	0.143313		

All OMR sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	53.17022	17.72341	129.2825	0.0000000
FERT	1	0.01622	0.01622	0.1183	0.7319278
HARV	2	0.75802	0.37901	2.7647	0.0703027
SITE:FERT	3	0.67381	0.22460	1.6384	0.1889408
SITE:HARV	6	1.41582	0.23597	1.7213	0.1298203
FERT:HARV	2	0.08621	0.04311	0.3144	0.7312844
SITE:FERT:HARV	6	0.79773	0.13295	0.9698	0.4526169
Residuals	66	9.04798	0.13709		

All OMR sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	11.89807	3.966023	50.54025	0.0000000
FERT	1	0.00900	0.008998	0.11466	0.7359706
HARV	2	0.12262	0.061309	0.78128	0.4620064
SITE:FERT	3	0.38720	0.129065	1.64472	0.1875153
SITE:HARV	6	0.69413	0.115688	1.47425	0.2006817
FERT:HARV	2	0.07162	0.035809	0.45633	0.6355916
SITE:FERT:HARV	6	0.52432	0.087386	1.11359	0.3640704
Residuals	66	5.17919	0.078473		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 continued

All OMR sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	6.716606	2.238869	28.54512	0.0000000
FERT	1	0.008501	0.008501	0.10838	0.7430363
HARV	2	0.206062	0.103031	1.31362	0.2757801
SITE:FERT	3	0.190264	0.063421	0.80861	0.4935994
SITE:HARV	6	0.359081	0.059847	0.76303	0.6015527
FERT:HARV	2	0.075369	0.037684	0.48047	0.6206402
SITE:FERT:HARV	6	0.137597	0.022933	0.29239	0.9385141
Residuals	66	5.176554	0.078433		

All OMR sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	18.33599	6.111997	35.21615	0.0000000
FERT	1	0.00018	0.000177	0.00102	0.9746436
HARV	2	0.51448	0.257239	1.48216	0.2346070
SITE:FERT	3	0.58249	0.194163	1.11873	0.3478953
SITE:HARV	6	0.83147	0.138578	0.79846	0.5745715
FERT:HARV	2	0.85623	0.428114	2.46671	0.0926551
SITE:FERT:HARV	6	1.31817	0.219695	1.26584	0.2852094
Residuals	66	11.45474	0.173557		

All OMR sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	106.9054	35.63512	92.54380	0.0000000
FERT	1	0.0526	0.05260	0.13660	0.7128722
HARV	2	0.9888	0.49438	1.28389	0.2837827
SITE:FERT	3	5.7604	1.92012	4.98651	0.0035310
SITE:HARV	6	3.6701	0.61168	1.58853	0.1644059
FERT:HARV	2	0.2313	0.11565	0.30033	0.7415802
SITE:FERT:HARV	6	6.2382	1.03971	2.70010	0.0209347
Residuals	66	25.4141	0.38506		

All OMR sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	23.67229	7.890765	40.81927	0.0000000
FERT	1	0.02004	0.020043	0.10368	0.7484718
HARV	2	0.99748	0.498739	2.58000	0.0833995
SITE:FERT	3	1.80358	0.601194	3.11000	0.0321918
SITE:HARV	6	0.68721	0.114535	0.59249	0.7351742
FERT:HARV	2	0.40341	0.201703	1.04342	0.3579850
SITE:FERT:HARV	6	2.41392	0.402320	2.08122	0.0671853
Residuals	66	12.75845	0.193310		

4.3.2: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003

All OMR sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	140.7926	46.93088	53.25650	0.0000000
FERT	1	4.6426	4.64264	5.26840	0.0249021
HARV	2	18.9297	9.46487	10.74060	0.0000916
SITE:FERT	3	4.9578	1.65260	1.87535	0.1423062
SITE:HARV	6	13.6674	2.27789	2.58492	0.0260517
FERT:HARV	2	17.8226	8.91132	10.11244	0.0001476
SITE:FERT:HARV	6	12.7922	2.13203	2.41939	0.0356378
Residuals	66	58.1608	0.88122		

All OMR sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	719.6097	239.8699	113.0020	0.0000000
FERT	1	4.1886	4.1886	1.9732	0.1647928
HARV	2	23.8060	11.9030	5.6075	0.0056339
SITE:FERT	3	16.3872	5.4624	2.5733	0.0613956
SITE:HARV	6	32.0164	5.3361	2.5138	0.0298108
FERT:HARV	2	6.5263	3.2632	1.5373	0.2225654
SITE:FERT:HARV	6	16.5473	2.7579	1.2992	0.2699206
Residuals	66	140.0985	2.1227		

All OMR sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	4.027370	1.342457	25.79457	0.0000000
FERT	1	0.160137	0.160137	3.07694	0.0840517
HARV	2	0.526089	0.263044	5.05426	0.0090710
SITE:FERT	3	0.051899	0.017300	0.33241	0.8019286
SITE:HARV	6	1.469893	0.244982	4.70720	0.0004808
FERT:HARV	2	0.467815	0.233908	4.49441	0.0147933
SITE:FERT:HARV	6	0.634859	0.105810	2.03308	0.0734608
Residuals	66	3.434913	0.052044		

All OMR sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	16.43094	5.476981	61.11593	0.0000000
FERT	1	0.75333	0.753327	8.40614	0.0050730
HARV	2	1.11864	0.559322	6.24130	0.0032918
SITE:FERT	3	0.47137	0.157123	1.75328	0.1647166
SITE:HARV	6	1.20311	0.200519	2.23752	0.0501836
FERT:HARV	2	1.66579	0.832897	9.29404	0.0002778
SITE:FERT:HARV	6	1.50459	0.250766	2.79821	0.0173718
Residuals	66	5.91467	0.089616		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003 continued

All OMR sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	8.788971	2.929657	29.72426	0.0000000
FERT	1	0.192599	0.192599	1.95410	0.1668259
HARV	2	1.960443	0.980222	9.94532	0.0001678
SITE:FERT	3	0.385094	0.128365	1.30238	0.2810708
SITE:HARV	6	0.716535	0.119422	1.21166	0.3115310
FERT:HARV	2	0.962508	0.481254	4.88280	0.0105286
SITE:FERT:HARV	6	1.140599	0.190100	1.92875	0.0890450
Residuals	66	6.505035	0.098561		

All OMR sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	9.631069	3.210356	53.81387	0.0000000
FERT	1	0.200437	0.200437	3.35985	0.0713149
HARV	2	1.451787	0.725893	12.16785	0.0000317
SITE:FERT	3	0.659342	0.219781	3.68409	0.0162204
SITE:HARV	6	0.632717	0.105453	1.76766	0.1194142
FERT:HARV	2	1.686323	0.843162	14.13357	0.0000078
SITE:FERT:HARV	6	0.699259	0.116543	1.95357	0.0850745
Residuals	66	3.937340	0.059657		

All OMR sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	9.005811	3.001937	47.74342	0.0000000
FERT	1	0.217830	0.217830	3.46442	0.0671568
HARV	2	0.392090	0.196045	3.11794	0.0508278
SITE:FERT	3	0.254683	0.084894	1.35017	0.2657568
SITE:HARV	6	1.473526	0.245588	3.90588	0.0021277
FERT:HARV	2	0.185405	0.092702	1.47436	0.2363663
SITE:FERT:HARV	6	0.386246	0.064374	1.02382	0.4177706
Residuals	66	4.149846	0.062876		

All OMR sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	36.00649	12.00216	89.68004	0.0000000
FERT	1	0.53571	0.53571	4.00281	0.0495406
HARV	2	1.19457	0.59729	4.46291	0.0152093
SITE:FERT	3	0.32834	0.10945	0.81778	0.4886433
SITE:HARV	6	1.98134	0.33022	2.46743	0.0325453
FERT:HARV	2	0.22150	0.11075	0.82750	0.4416227
SITE:FERT:HARV	6	0.41991	0.06999	0.52293	0.7889132
Residuals	66	8.83299	0.13383		

All OMR sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	150.6965	50.23218	109.5695	0.0000000
FERT	1	0.5934	0.59341	1.2944	0.2593550
HARV	2	4.1430	2.07149	4.5185	0.0144835
SITE:FERT	3	4.9162	1.63873	3.5745	0.0184780
SITE:HARV	6	4.8847	0.81411	1.7758	0.1176745
FERT:HARV	2	0.7134	0.35669	0.7780	0.4634738
SITE:FERT:HARV	6	5.4149	0.90248	1.9685	0.0827600
Residuals	66	30.2577	0.45845		

All OMR sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	34.63190	11.54397	87.53547	0.0000000
FERT	1	0.00603	0.00603	0.04570	0.8313740
HARV	2	1.41561	0.70781	5.36714	0.0069231
SITE:FERT	3	0.70854	0.23618	1.79091	0.1574634
SITE:HARV	6	1.03923	0.17320	1.31337	0.2636539
FERT:HARV	2	0.78401	0.39200	2.97248	0.0580683
SITE:FERT:HARV	6	0.93175	0.15529	1.17754	0.3290871
Residuals	66	8.70392	0.13188		

All OMR sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	84.26492	28.08831	69.62790	0.0000000
FERT	1	0.01936	0.01936	0.04800	0.8272576
HARV	2	3.33351	1.66676	4.13171	0.0203881
SITE:FERT	3	2.18532	0.72844	1.80573	0.1546939
SITE:HARV	6	4.09169	0.68195	1.69048	0.1371859
FERT:HARV	2	2.07776	1.03888	2.57527	0.0837664
SITE:FERT:HARV	6	0.73733	0.12289	0.30463	0.9323797
Residuals	66	26.62479	0.40341		

All OMR sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	130.2562	43.41875	48.16182	0.0000000
FERT	1	0.0131	0.01312	0.01456	0.9043322
HARV	2	14.3470	7.17349	7.95712	0.0008018
SITE:FERT	3	7.7463	2.58210	2.86417	0.0432517
SITE:HARV	6	15.6023	2.60039	2.88446	0.0147426
FERT:HARV	2	2.4370	1.21848	1.35159	0.2658980
SITE:FERT:HARV	6	1.4696	0.24494	0.27169	0.9482737
Residuals	66	59.5002	0.90152		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2003 continued

All OMR sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3.052832	1.017611	40.14081	0.0000000
FERT	1	0.022863	0.022863	0.90187	0.3457452
HARV	2	0.027821	0.013910	0.54871	0.5803043
SITE:FERT	3	0.143214	0.047738	1.88308	0.1409919
SITE:HARV	6	0.158410	0.026402	1.04144	0.4068084
FERT:HARV	2	0.030666	0.015333	0.60484	0.5491625
SITE:FERT:HARV	6	0.162590	0.027098	1.06892	0.3901203
Residuals	66	1.673168	0.025351		

All OMR sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	8.533805	2.844602	63.56278	0.0000000
FERT	1	0.000714	0.000714	0.01596	0.8998629
HARV	2	0.341695	0.170848	3.81760	0.0269854
SITE:FERT	3	0.121395	0.040465	0.90419	0.4439341
SITE:HARV	6	0.385034	0.064172	1.43393	0.2150846
FERT:HARV	2	0.337766	0.168883	3.77370	0.0280690
SITE:FERT:HARV	6	0.259231	0.043205	0.96542	0.4555432
Residuals	66	2.953674	0.044753		

All OMR sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	6.016735	2.005578	52.19251	0.0000000
FERT	1	0.000000	0.000000	0.00000	0.9985512
HARV	2	0.305954	0.152977	3.98102	0.0233162
SITE:FERT	3	0.128629	0.042876	1.11580	0.3490703
SITE:HARV	6	0.285655	0.047609	1.23896	0.2980294
FERT:HARV	2	0.087929	0.043964	1.14411	0.3247406
SITE:FERT:HARV	6	0.069037	0.011506	0.29943	0.9350156
Residuals	66	2.536153	0.038427		

All OMR sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	4.445224	1.481741	47.56005	0.0000000
FERT	1	0.000226	0.000226	0.00725	0.9324176
HARV	2	0.351760	0.175880	5.64528	0.0054548
SITE:FERT	3	0.337405	0.112468	3.60995	0.0177150
SITE:HARV	6	0.391719	0.065286	2.09552	0.0654227
FERT:HARV	2	0.198625	0.099313	3.18768	0.0476931
SITE:FERT:HARV	6	0.069000	0.011500	0.36912	0.8959917
Residuals	66	2.056241	0.031155		

All OMR sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1.281069	0.4270230	15.43499	0.0000001
FERT	1	0.078241	0.0782409	2.82806	0.0973565
HARV	2	0.314007	0.1570035	5.67498	0.0053182
SITE:FERT	3	0.173402	0.0578005	2.08923	0.1100435
SITE:HARV	6	0.305392	0.0508986	1.83976	0.1047797
FERT:HARV	2	0.057342	0.0286711	1.03633	0.3604528
SITE:FERT:HARV	6	0.242743	0.0404571	1.46234	0.2048427
Residuals	66	1.825950	0.0276659		

All OMR sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	7.010530	2.336843	38.18172	0.0000000
FERT	1	0.017264	0.017264	0.28207	0.5971290
HARV	2	0.503984	0.251992	4.11730	0.0206509
SITE:FERT	3	0.467774	0.155925	2.54766	0.0633245
SITE:HARV	6	1.332797	0.222133	3.62943	0.0035817
FERT:HARV	2	0.288322	0.144161	2.35545	0.1027781
SITE:FERT:HARV	6	0.237821	0.039637	0.64763	0.6917740
Residuals	66	4.039411	0.061203		

All OMR sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	28.46873	9.489578	39.90847	0.0000000
FERT	1	0.37772	0.377723	1.58852	0.2119759
HARV	2	1.47031	0.735153	3.09169	0.0520621
SITE:FERT	3	1.45864	0.486212	2.04477	0.1160934
SITE:HARV	6	2.89962	0.483270	2.03239	0.0735537
FERT:HARV	2	0.15866	0.079329	0.33362	0.7175268
SITE:FERT:HARV	6	0.31987	0.053311	0.22420	0.9675654
Residuals	66	15.69372	0.237784		

All OMR sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	7.000911	2.333637	37.93371	0.0000000
FERT	1	0.101151	0.101151	1.64424	0.2042310
HARV	2	1.885411	0.942705	15.32385	0.0000034
SITE:FERT	3	0.458840	0.152947	2.48617	0.0681973
SITE:HARV	6	0.760278	0.126713	2.05974	0.0699184
FERT:HARV	2	0.183985	0.091993	1.49536	0.2316638
SITE:FERT:HARV	6	0.299025	0.049838	0.81012	0.5658030
Residuals	66	4.060243	0.061519		

4.3.3: ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003

All OMR sites FH Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	209.2002	69.7334	24.7061	0.0000000
YEAR	1	370.7866	370.7866	131.3675	0.0000000
FERT	1	8.2601	8.2601	2.9265	0.0894858
HARV	2	21.8633	10.9316	3.8730	0.0231993
SITE:YEAR	3	103.2041	34.4014	12.1882	0.0000004
SITE:FERT	3	7.5492	2.5164	0.8915	0.4474344
YEAR:FERT	1	0.0300	0.0300	0.0106	0.9180729
SITE:HARV	6	8.8232	1.4705	0.5210	0.7915884
YEAR:HARV	2	9.9950	4.9975	1.7706	0.1742520
FERT:HARV	2	28.9096	14.4548	5.1212	0.0072101
SITE:YEAR:FERT	3	2.7433	0.9144	0.3240	0.8080169
SITE:YEAR:HARV	6	28.6566	4.7761	1.6921	0.1277215
SITE:FERT:HARV	6	14.8151	2.4692	0.8748	0.5153478
YEAR:FERT:HARV	2	2.1665	1.0832	0.3838	0.6820364
SITE:YEAR:FERT:HARV	6	7.7702	1.2950	0.4588	0.8376359
Residuals	132	372.5719	2.8225		

All OMR sites FH Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	1446.741	482.247	91.2520	0.0000000
YEAR	1	1423.832	1423.832	269.4210	0.0000000
FERT	1	30.856	30.856	5.8387	0.0170452
HARV	2	53.609	26.804	5.0720	0.0075475
SITE:YEAR	3	439.005	146.335	27.6899	0.0000000
SITE:FERT	3	10.493	3.498	0.6619	0.5769331
YEAR:FERT	1	7.078	7.078	1.3394	0.2492385
SITE:HARV	6	8.265	1.377	0.2606	0.9541415
YEAR:HARV	2	4.787	2.394	0.4529	0.6367507
FERT:HARV	2	13.174	6.587	1.2464	0.2908956
SITE:YEAR:FERT	3	11.759	3.920	0.7417	0.5290393
SITE:YEAR:HARV	6	63.340	10.557	1.9976	0.0704027
SITE:FERT:HARV	6	37.600	6.267	1.1858	0.3177453
YEAR:FERT:HARV	2	2.504	1.252	0.2369	0.7893840
SITE:YEAR:FERT:HARV	6	29.837	4.973	0.9410	0.4680858
Residuals	132	697.591	5.285		

All OMR sites FH Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	6.28196	2.09399	19.34155	0.0000000
YEAR	1	10.64213	10.64213	98.29825	0.0000000
FERT	1	0.45996	0.45996	4.24853	0.0412474
HARV	2	0.92643	0.46322	4.27860	0.0158334
SITE:YEAR	3	1.40452	0.46817	4.32439	0.0060719
SITE:FERT	3	0.08645	0.02882	0.26618	0.8496695
YEAR:FERT	1	0.01261	0.01261	0.11644	0.7334707
SITE:HARV	6	0.24176	0.04029	0.37217	0.8955684
YEAR:HARV	2	0.34327	0.17163	1.58534	0.2087539
FERT:HARV	2	0.63393	0.31697	2.92774	0.0570027
SITE:YEAR:FERT	3	0.04559	0.01520	0.14037	0.9356526
SITE:YEAR:HARV	6	2.39994	0.39999	3.69460	0.0019957
SITE:FERT:HARV	6	0.74133	0.12355	1.14124	0.3420650
YEAR:FERT:HARV	2	0.04957	0.02478	0.22892	0.7957098
SITE:YEAR:FERT:HARV	6	0.45247	0.07541	0.69655	0.6528185
Residuals	132	14.29080	0.10826		

All OMR sites FH Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	18.85862	6.28621	28.79208	0.0000000
YEAR	1	20.22556	20.22556	92.63710	0.0000000
FERT	1	1.05247	1.05247	4.82051	0.0298706
HARV	2	1.41198	0.70599	3.23358	0.0425592
SITE:YEAR	3	6.66254	2.22085	10.17191	0.0000045
SITE:FERT	3	1.53172	0.51057	2.33853	0.0764560
YEAR:FERT	1	0.04063	0.04063	0.18608	0.6669046
SITE:HARV	6	0.81281	0.13547	0.62047	0.7136309
YEAR:HARV	2	0.65067	0.32533	1.49009	0.2291171
FERT:HARV	2	2.29475	1.14737	5.25520	0.0063680
SITE:YEAR:FERT	3	0.37432	0.12477	0.57149	0.6347447
SITE:YEAR:HARV	6	3.07221	0.51204	2.34522	0.0348188
SITE:FERT:HARV	6	1.69189	0.28198	1.29153	0.2654231
YEAR:FERT:HARV	2	0.19815	0.09907	0.45378	0.6362111
SITE:YEAR:FERT:HARV	6	0.71467	0.11911	0.54555	0.7727069
Residuals	132	28.81970	0.21833		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS
SUMMER 2002 and 2003 continued

All OMR sites FH Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	19.42779	6.47593	19.2195	0.0000000
YEAR	1	42.07462	42.07462	124.8707	0.0000000
FERT	1	0.21817	0.21817	0.6475	0.4224580
HARV	2	1.21635	0.60817	1.8050	0.1685170
SITE:YEAR	3	14.15282	4.71761	14.0011	0.0000001
SITE:FERT	3	0.37163	0.12388	0.3676	0.7764709
YEAR:FERT	1	0.02358	0.02358	0.0700	0.7917773
SITE:HARV	6	1.51399	0.25233	0.7489	0.6113504
YEAR:HARV	2	1.31070	0.65535	1.9450	0.1470676
FERT:HARV	2	2.52280	1.26140	3.7436	0.0262181
SITE:YEAR:FERT	3	0.42241	0.14080	0.4179	0.7404594
SITE:YEAR:HARV	6	1.12473	0.18746	0.5563	0.7643190
SITE:FERT:HARV	6	2.03540	0.33923	1.0068	0.4237145
YEAR:FERT:HARV	2	0.27891	0.13945	0.4139	0.6619388
SITE:YEAR:FERT:HARV	6	0.91583	0.15264	0.4530	0.8417826
Residuals	132	44.47681	0.33695		

All OMR sites FH Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	12.85564	4.28521	23.4326	0.0000000
YEAR	1	25.09932	25.09932	137.2489	0.0000000
FERT	1	0.49414	0.49414	2.7021	0.1025973
HARV	2	2.22102	1.11051	6.0725	0.0029998
SITE:YEAR	3	8.28018	2.76006	15.0927	0.0000000
SITE:FERT	3	0.56890	0.18963	1.0370	0.3784973
YEAR:FERT	1	0.00487	0.00487	0.0266	0.8705839
SITE:HARV	6	0.81861	0.13644	0.7461	0.6135689
YEAR:HARV	2	0.51816	0.25908	1.4167	0.2461737
FERT:HARV	2	2.36179	1.18090	6.4574	0.0021107
SITE:YEAR:FERT	3	0.21136	0.07045	0.3853	0.7637947
SITE:YEAR:HARV	6	1.34651	0.22442	1.2272	0.2963777
SITE:FERT:HARV	6	0.88288	0.14715	0.8046	0.5680311
YEAR:FERT:HARV	2	0.23753	0.11877	0.6494	0.5240006
SITE:YEAR:FERT:HARV	6	0.40038	0.06673	0.3649	0.9000001
Residuals	132	24.13942	0.18287		

All OMR sites FH Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	31.86956	10.62319	75.7114	0.0000000
YEAR	1	33.48265	33.48265	238.6307	0.0000000
FERT	1	1.43994	1.43994	10.2625	0.0017021
HARV	2	1.26510	0.63255	4.5082	0.0127670
SITE:YEAR	3	7.42211	2.47404	17.6324	0.0000000
SITE:FERT	3	0.22061	0.07354	0.5241	0.6664616
YEAR:FERT	1	0.29153	0.29153	2.0777	0.1518332
SITE:HARV	6	0.17285	0.02881	0.2053	0.9746216
YEAR:HARV	2	0.12391	0.06195	0.4415	0.6439854
FERT:HARV	2	0.20547	0.10273	0.7322	0.4827984
SITE:YEAR:FERT	3	0.19351	0.06450	0.4597	0.7108933
SITE:YEAR:HARV	6	2.44394	0.40732	2.9030	0.0108504
SITE:FERT:HARV	6	0.60502	0.10084	0.7187	0.6352321
YEAR:FERT:HARV	2	0.03495	0.01747	0.1245	0.8830063
SITE:YEAR:FERT:HARV	6	0.30714	0.05119	0.3648	0.9000425
Residuals	132	18.52113	0.14031		

All OMR sites FH Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	67.13768	22.37923	62.6209	0.0000000
YEAR	1	42.65674	42.65674	119.3608	0.0000000
FERT	1	1.81961	1.81961	5.0916	0.0256865
HARV	2	2.44849	1.22424	3.4256	0.0354476
SITE:YEAR	3	17.38073	5.79358	16.2114	0.0000000
SITE:FERT	3	0.45573	0.15191	0.4251	0.7353448
YEAR:FERT	1	0.09849	0.09849	0.2756	0.6004811
SITE:HARV	6	0.58817	0.09803	0.2743	0.9481475
YEAR:HARV	2	0.28039	0.14019	0.3923	0.6762956
FERT:HARV	2	0.29126	0.14563	0.4075	0.6661482
SITE:YEAR:FERT	3	0.32187	0.10729	0.3002	0.8251892
SITE:YEAR:HARV	6	2.72748	0.45458	1.2720	0.2745314
SITE:FERT:HARV	6	2.00892	0.33482	0.9369	0.4709324
YEAR:FERT:HARV	2	0.02313	0.01157	0.0324	0.9681633
SITE:YEAR:FERT:HARV	6	0.98309	0.16385	0.4585	0.8378848
Residuals	132	47.17368	0.35738		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003 continued

All OMR sites FH Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	233.1771	77.7257	74.9818	0.0000000
YEAR	1	258.5521	258.5521	249.4245	0.0000000
FERT	1	3.9510	3.9510	3.8115	0.0530190
HARV	2	6.9378	3.4689	3.3465	0.0382206
SITE:YEAR	3	97.7028	32.5676	31.4179	0.0000000
SITE:FERT	3	3.5384	1.1795	1.1378	0.3362882
YEAR:FERT	1	0.8069	0.8069	0.7784	0.3792235
SITE:HARV	6	4.1569	0.6928	0.6684	0.6753406
YEAR:HARV	2	1.1097	0.5548	0.5353	0.5867847
FERT:HARV	2	3.5341	1.7671	1.7047	0.1858103
SITE:YEAR:FERT	3	3.0300	1.0100	0.9743	0.4069763
SITE:YEAR:HARV	6	12.5836	2.0973	2.0232	0.0668938
SITE:FERT:HARV	6	11.9720	1.9953	1.9249	0.0813068
YEAR:FERT:HARV	2	1.4431	0.7216	0.6961	0.5003550
SITE:YEAR:FERT:HARV	6	6.6358	1.1060	1.0669	0.3856705
Residuals	132	136.8305	1.0366		

All OMR sites FH Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	85.83579	28.61193	94.2729	0.0000000
YEAR	1	87.16970	87.16970	287.2136	0.0000000
FERT	1	1.03670	1.03670	3.4158	0.0668126
HARV	2	4.47529	2.23765	7.3728	0.0009217
SITE:YEAR	3	20.39333	6.79778	22.3979	0.0000000
SITE:FERT	3	0.24192	0.08064	0.2657	0.8500159
YEAR:FERT	1	0.82518	0.82518	2.7189	0.1015468
SITE:HARV	6	0.79402	0.13234	0.4360	0.8536894
YEAR:HARV	2	0.27643	0.13821	0.4554	0.6351895
FERT:HARV	2	1.16267	0.58134	1.9154	0.1513498
SITE:YEAR:FERT	3	0.59481	0.19827	0.6533	0.5822720
SITE:YEAR:HARV	6	2.24052	0.37342	1.2304	0.2947714
SITE:FERT:HARV	6	2.02578	0.33763	1.1125	0.3585032
YEAR:FERT:HARV	2	0.36472	0.18236	0.6008	0.5498389
SITE:YEAR:FERT:HARV	6	2.72494	0.45416	1.4964	0.1841700
Residuals	132	40.06217	0.30350		

All OMR sites Soil Substrate Utilisation (120 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	54.7583	18.2528	23.2527	0.0000000
YEAR	1	407.7566	407.7566	519.4513	0.0000000
FERT	1	0.0215	0.0215	0.0274	0.8688281
HARV	2	6.8703	3.4351	4.3761	0.0144490
SITE:YEAR	3	260.9405	86.9802	110.8062	0.0000000
SITE:FERT	3	7.2715	2.4238	3.0878	0.0294734
YEAR:FERT	1	0.1179	0.1179	0.1502	0.6989488
SITE:HARV	6	6.2158	1.0360	1.3197	0.2527079
YEAR:HARV	2	0.3257	0.1629	0.2075	0.8129054
FERT:HARV	2	0.3280	0.1640	0.2089	0.8117468
SITE:YEAR:FERT	3	1.1405	0.3802	0.4843	0.6937719
SITE:YEAR:HARV	6	11.5322	1.9220	2.4485	0.0281343
SITE:FERT:HARV	6	3.4658	0.5776	0.7359	0.6216025
YEAR:FERT:HARV	2	2.6714	1.3357	1.7016	0.1863666
SITE:YEAR:FERT:HARV	6	2.9312	0.4885	0.6224	0.7121268
Residuals	132	103.6168	0.7850		

All OMR sites Soil Substrate Utilisation (240 Hours)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	416.5448	138.8483	84.0423	0.0000000
YEAR	1	622.2229	622.2229	376.6201	0.0000000
FERT	1	0.0114	0.0114	0.0069	0.9339808
HARV	2	17.4308	8.7154	5.2753	0.0062508
SITE:YEAR	3	193.0200	64.3400	38.9438	0.0000000
SITE:FERT	3	28.5525	9.5175	5.7608	0.0009834
YEAR:FERT	1	0.0722	0.0722	0.0437	0.8347401
SITE:HARV	6	12.7281	2.1214	1.2840	0.2688955
YEAR:HARV	2	3.8504	1.9252	1.1653	0.3150215
FERT:HARV	2	0.6597	0.3299	0.1997	0.8192535
SITE:YEAR:FERT	3	2.9364	0.9788	0.5925	0.6210089
SITE:YEAR:HARV	6	19.4919	3.2486	1.9663	0.0749075
SITE:FERT:HARV	6	10.0305	1.6717	1.0119	0.4204032
YEAR:FERT:HARV	2	5.9938	2.9969	1.8140	0.1670451
SITE:YEAR:FERT:HARV	6	18.3232	3.0539	1.8485	0.0944684
Residuals	132	218.0803	1.6521		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003 continued

All OMR sites Soil Substrate Utilisation (120 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	0.229608	0.076536	2.1528	0.0966479
YEAR	1	8.958609	8.958609	251.9915	0.0000000
FERT	1	0.016343	0.016343	0.4597	0.4989523
HARV	2	0.152320	0.076160	2.1423	0.1214538
SITE:YEAR	3	4.451303	1.483768	41.7360	0.0000000
SITE:FERT	3	0.122732	0.040911	1.1507	0.3311919
YEAR:FERT	1	0.007396	0.007396	0.2080	0.6490628
SITE:HARV	6	0.279437	0.046573	1.3100	0.2570319
YEAR:HARV	2	0.091125	0.045562	1.2816	0.2810239
FERT:HARV	2	0.018238	0.009119	0.2565	0.7741428
SITE:YEAR:FERT	3	0.119969	0.039990	1.1249	0.3414706
SITE:YEAR:HARV	6	0.362647	0.060441	1.7001	0.1257958
SITE:FERT:HARV	6	0.144499	0.024083	0.6774	0.6680968
YEAR:FERT:HARV	2	0.039925	0.019963	0.5615	0.5716994
SITE:YEAR:FERT:HARV	6	0.101111	0.016852	0.4740	0.8266643
Residuals	132	4.692763	0.035551		

All OMR sites Soil Substrate Utilisation (120 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	3.51836	1.17279	12.4721	0.0000003
YEAR	1	25.28958	25.28958	268.9441	0.0000000
FERT	1	0.03622	0.03622	0.3851	0.5359343
HARV	2	0.40445	0.20222	2.1506	0.1204813
SITE:YEAR	3	15.28838	5.09613	54.1952	0.0000000
SITE:FERT	3	0.77976	0.25992	2.7641	0.0445358
YEAR:FERT	1	0.02326	0.02326	0.2474	0.6197650
SITE:HARV	6	0.63081	0.10514	1.1181	0.3552478
YEAR:HARV	2	0.08248	0.04124	0.4386	0.6458845
FERT:HARV	2	0.29039	0.14520	1.5441	0.2173344
SITE:YEAR:FERT	3	0.26121	0.08707	0.9259	0.4302353
SITE:YEAR:HARV	6	1.11204	0.18534	1.9710	0.0742166
SITE:FERT:HARV	6	1.01161	0.16860	1.7930	0.1052237
YEAR:FERT:HARV	2	0.52967	0.26484	2.8164	0.0634185
SITE:YEAR:FERT:HARV	6	0.47402	0.07900	0.8402	0.5410668
Residuals	132	12.41234	0.09403		

All OMR sites Soil Substrate Utilisation (120 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	17.94312	5.98104	68.1534	0.0000000
YEAR	1	52.96791	52.96791	603.5641	0.0000000
FERT	1	0.00816	0.00816	0.0930	0.7609322
HARV	2	1.00960	0.50480	5.7522	0.0040253
SITE:YEAR	3	41.24383	13.74794	156.6565	0.0000000
SITE:FERT	3	0.57782	0.19261	2.1947	0.0916806
YEAR:FERT	1	0.00807	0.00807	0.0919	0.7622287
SITE:HARV	6	0.56847	0.09475	1.0796	0.3779547
YEAR:HARV	2	0.05437	0.02719	0.3098	0.7341373
FERT:HARV	2	0.02279	0.01140	0.1299	0.8783388
SITE:YEAR:FERT	3	0.22463	0.07488	0.8532	0.4672751
SITE:YEAR:HARV	6	1.13300	0.18883	2.1517	0.0516681
SITE:FERT:HARV	6	0.35857	0.05976	0.6810	0.6652506
YEAR:FERT:HARV	2	0.15135	0.07568	0.8623	0.4245463
SITE:YEAR:FERT:HARV	6	0.50819	0.08470	0.9651	0.4514791
Residuals	132	11.58413	0.08776		

All OMR sites Soil Substrate Utilisation (120 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	2.38352	0.79451	14.4946	0.0000000
YEAR	1	23.33352	23.33352	425.6864	0.0000000
FERT	1	0.00319	0.00319	0.0581	0.8098436
HARV	2	0.35946	0.17973	3.2789	0.0407594
SITE:YEAR	3	13.95977	4.65326	84.8920	0.0000000
SITE:FERT	3	0.71238	0.23746	4.3321	0.0060126
YEAR:FERT	1	0.00604	0.00604	0.1101	0.7405117
SITE:HARV	6	0.41946	0.06991	1.2754	0.2729278
YEAR:HARV	2	0.11492	0.05746	1.0483	0.3534490
FERT:HARV	2	0.05421	0.02711	0.4945	0.6109794
SITE:YEAR:FERT	3	0.01223	0.00408	0.0743	0.9736780
SITE:YEAR:HARV	6	0.66639	0.11107	2.0262	0.0664942
SITE:FERT:HARV	6	0.28649	0.04775	0.8711	0.5180886
YEAR:FERT:HARV	2	0.21603	0.10801	1.9706	0.1434568
SITE:YEAR:FERT:HARV	6	0.30683	0.05114	0.9329	0.4736826
Residuals	132	7.23543	0.05481		

ORGANIC MATTER REMOVAL AT WOODHILL, TARAWERA, KINLEITH and GOLDEN DOWNS SUMMER 2002 and 2003 continued

All OMR sites Soil Substrate Utilisation (240 Hours) Amino Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	5.556003	1.852001	34.9110	0.0000000
YEAR	1	8.154678	8.154678	153.7189	0.0000000
FERT	1	0.069160	0.069160	1.3037	0.2556056
HARV	2	0.493625	0.246812	4.6525	0.0111552
SITE:YEAR	3	2.441673	0.813891	15.3422	0.0000000
SITE:FERT	3	0.215065	0.071688	1.3514	0.2605919
YEAR:FERT	1	0.017581	0.017581	0.3314	0.5658083
SITE:HARV	6	0.197413	0.032902	0.6202	0.7138295
YEAR:HARV	2	0.026444	0.013222	0.2492	0.7797584
FERT:HARV	2	0.027490	0.013745	0.2591	0.7721348
SITE:YEAR:FERT	3	0.148601	0.049534	0.9337	0.4264185
SITE:YEAR:HARV	6	0.467059	0.077843	1.4674	0.1941854
SITE:FERT:HARV	6	0.047142	0.007857	0.1481	0.9891525
YEAR:FERT:HARV	2	0.105220	0.052610	0.9917	0.3736832
SITE:YEAR:FERT:HARV	6	0.333198	0.055533	1.0468	0.3981183
Residuals	132	7.002504	0.053049		

All OMR sites Soil Substrate Utilisation (240 Hours) Carboxylic Acids

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	19.21612	6.40537	54.5696	0.0000000
YEAR	1	22.02939	22.02939	187.6760	0.0000000
FERT	1	0.01047	0.01047	0.0892	0.7657059
HARV	2	0.51306	0.25653	2.1855	0.1164762
SITE:YEAR	3	6.13040	2.04347	17.4090	0.0000000
SITE:FERT	3	1.04409	0.34803	2.9650	0.0344749
YEAR:FERT	1	0.00697	0.00697	0.0594	0.8078064
SITE:HARV	6	0.98085	0.16348	1.3927	0.2221540
YEAR:HARV	2	0.50540	0.25270	2.1528	0.1202143
FERT:HARV	2	0.30356	0.15178	1.2931	0.2778755
SITE:YEAR:FERT	3	0.00618	0.00206	0.0175	0.9968222
SITE:YEAR:HARV	6	1.18341	0.19724	1.6803	0.1306283
SITE:FERT:HARV	6	0.84594	0.14099	1.2011	0.3096845
YEAR:FERT:HARV	2	0.84099	0.42049	3.5823	0.0305471
SITE:YEAR:FERT:HARV	6	0.71005	0.11834	1.0082	0.4227985
Residuals	132	15.49415	0.11738		

All OMR sites Soil Substrate Utilisation (240 Hours) Carbohydrates

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	80.7064	26.9021	86.3846	0.0000000
YEAR	1	140.1938	140.1938	450.1719	0.0000000
FERT	1	0.3561	0.3561	1.1435	0.2868652
HARV	2	2.4016	1.2008	3.8558	0.0235797
SITE:YEAR	3	54.6677	18.2226	58.5139	0.0000000
SITE:FERT	3	6.4692	2.1564	6.9244	0.0002299
YEAR:FERT	1	0.0742	0.0742	0.2383	0.6262544
SITE:HARV	6	2.3118	0.3853	1.2372	0.2913599
YEAR:HARV	2	0.0575	0.0287	0.0923	0.9118781
FERT:HARV	2	0.0717	0.0358	0.1151	0.8913546
SITE:YEAR:FERT	3	0.7497	0.2499	0.8025	0.4946047
SITE:YEAR:HARV	6	4.2579	0.7097	2.2787	0.0399040
SITE:FERT:HARV	6	2.9756	0.4959	1.5925	0.1541596
YEAR:FERT:HARV	2	0.3183	0.1591	0.5110	0.6010978
SITE:YEAR:FERT:HARV	6	3.5825	0.5971	1.9173	0.0825393
Residuals	132	41.1078	0.3114		

All OMR sites Soil Substrate Utilisation (240 Hours) N and P sources

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
SITE	3	23.27196	7.75732	60.8827	0.0000000
YEAR	1	30.85648	30.85648	242.1744	0.0000000
FERT	1	0.01557	0.01557	0.1222	0.7272105
HARV	2	2.13139	1.06569	8.3640	0.0003802
SITE:YEAR	3	7.40124	2.46708	19.3627	0.0000000
SITE:FERT	3	1.98011	0.66004	5.1802	0.0020463
YEAR:FERT	1	0.10562	0.10562	0.8290	0.3642282
SITE:HARV	6	0.77640	0.12940	1.0156	0.4180010
YEAR:HARV	2	0.75150	0.37575	2.9490	0.0558515
FERT:HARV	2	0.04966	0.02483	0.1949	0.8231803
SITE:YEAR:FERT	3	0.28231	0.09410	0.7386	0.5308494
SITE:YEAR:HARV	6	0.67109	0.11185	0.8778	0.5131436
SITE:FERT:HARV	6	0.95622	0.15937	1.2508	0.2846916
YEAR:FERT:HARV	2	0.53773	0.26887	2.1102	0.1252869
SITE:YEAR:FERT:HARV	6	1.75673	0.29279	2.2979	0.0383685
Residuals	132	16.81869	0.12741		

STATISTICAL APPENDIX FIVE: Litterfall Mass and Nutrient Content ANOVA Outputs

5.1: COLLECTIONS AT WOODHILL

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Woodhill Litterfall Mass per Day Collection One
          Df Sum of Sq    Mean Sq   F Value     Pr(F)
     FERT  1 0.0163503 0.01635035 0.9933770 0.3385922
     HARV  2 0.0100328 0.00501640 0.3047748 0.7428310
FERT:HARV  2 0.0005692 0.00028460 0.0172911 0.9828820
Residuals 12 0.1975123 0.01645936
Woodhill Litterfall Carbon Content Collection One
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.048391 0.0483912 0.090389 0.7688286
     HARV  2  0.228983 0.1144913 0.213856 0.8104767
FERT:HARV  2  1.137451 0.5687254 1.062309 0.3760340
Residuals 12  6.424406 0.5353671
Woodhill Litterfall Nitrogen Content Collection One
          Df Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.0708111 0.07081109 7.375072 0.0187562
     HARV  2 0.0494531 0.02472656 2.575305 0.1173303
FERT:HARV  2 0.0307536 0.01537679 1.601514 0.2418283
Residuals 12 0.1152169 0.00960141
Woodhill Litterfall Carbon:Nitrogen Ratio Collection One
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  458.8856 458.8856 8.384371 0.0134362
     HARV  2  245.6422 122.8211 2.244084 0.1486117
FERT:HARV  2  175.3169  87.6585 1.601622 0.2418076
Residuals 12  656.7728  54.7311

Woodhill Litterfall Mass per Day Collection Two
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1 0.1525855 0.1525855 3.300501 0.0943034
     HARV  2 0.0093845 0.0046923 0.101496 0.9042520
FERT:HARV  2 0.0110767 0.0055384 0.119798 0.8881476
Residuals 12 0.5547720 0.0462310
Woodhill Litterfall Carbon Content Collection Two
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.268645 0.2686448 2.467096 0.1422332
     HARV  2  0.112955 0.0564774 0.518659 0.6080759
FERT:HARV  2  0.424365 0.2121827 1.948577 0.1849997
Residuals 12  1.306693 0.1088911
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Woodhill Litterfall Nitrogen Content Collection Two
          Df  Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.05779653 0.05779653 9.244253 0.0102655
     HARV  2 0.00084998 0.00042499 0.067975 0.9346407
FERT:HARV  2 0.00171764 0.00085882 0.137364 0.8730039
Residuals 12 0.07502589 0.00625216
Woodhill Litterfall Carbon:Nitrogen Ratio Collection Two
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  339.5225 339.5225 10.23025 0.0076541
     HARV  2    3.4063   1.7031  0.05132 0.9501843
FERT:HARV  2    2.0981   1.0491  0.03161 0.9689650
Residuals 12  398.2570  33.1881

Woodhill Litterfall Mass per Day Collection Three
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1 0.2182020 0.2182020 4.444340 0.0567167
     HARV  2 0.0205778 0.0102889 0.209564 0.8138431
FERT:HARV  2 0.0706956 0.0353478 0.719964 0.5066475
Residuals 12 0.5891593 0.0490966
Woodhill Litterfall Carbon Content Collection Three
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1 0.0166251 0.0166251 0.208995 0.6557219
     HARV  2 0.9739861 0.4869931 6.122020 0.0147047
FERT:HARV  2 0.1612239 0.0806119 1.013378 0.3920524
Residuals 12 0.9545732 0.0795478
Woodhill Litterfall Nitrogen Content Collection Three
          Df Sum of Sq    Mean Sq  F Value     Pr(F)
     FERT  1 0.0366432 0.03664322 2.470599 0.1419750
     HARV  2 0.0165175 0.00825874 0.556830 0.5871432
FERT:HARV  2 0.0025315 0.00126574 0.085340 0.9187522
Residuals 12 0.1779806 0.01483172
Woodhill Litterfall Carbon:Nitrogen Ratio Collection Three
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   260.904 260.9035 2.418829 0.1458514
     HARV  2   116.550  58.2751 0.540267 0.5961215
FERT:HARV  2    17.577   8.7884 0.081477 0.9222598
Residuals 12  1294.363 107.8636
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COLLECTIONS AT WOODHILL continued

Woodhill Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	1.974802	0.9874009	26.49864	0.0000001
FERT	1	0.323810	0.3238099	8.69001	0.0055870
HARV	2	0.002208	0.0011038	0.02962	0.9708346
COLLECTION:FERT	2	0.063328	0.0316640	0.84976	0.4359143
COLLECTION:HARV	4	0.037787	0.0094469	0.25352	0.9056113
FERT:HARV	2	0.051406	0.0257029	0.68978	0.5081925
COLLECTION:FERT:HARV	4	0.030936	0.0077339	0.20755	0.9325601
Residuals	36	1.341444	0.0372623		

Woodhill Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	3.162063	1.581032	6.552992	0.0037413
FERT	1	0.060853	0.060853	0.252219	0.6185749
HARV	2	0.984556	0.492278	2.040373	0.1447441
COLLECTION:FERT	2	0.272809	0.136404	0.565362	0.5731170
COLLECTION:HARV	4	0.331367	0.082842	0.343359	0.8468490
FERT:HARV	2	0.780174	0.390087	1.616815	0.2126141
COLLECTION:FERT:HARV	4	0.942866	0.235717	0.976988	0.4322137
Residuals	36	8.685672	0.241269		

Woodhill Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	0.0075747	0.00378734	0.370276	0.6931428
FERT	1	0.0091554	0.00915545	0.895098	0.3504068
HARV	2	0.0198187	0.00990937	0.968807	0.3892107
COLLECTION:FERT	2	0.1560954	0.07804769	7.630468	0.0017270
COLLECTION:HARV	4	0.0470018	0.01175046	1.148804	0.3494764
FERT:HARV	2	0.0148192	0.00740961	0.724414	0.4915380
COLLECTION:FERT:HARV	4	0.0201835	0.00504587	0.493318	0.7406340
Residuals	36	0.3682234	0.01022843		

Woodhill Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	64.247	32.1233	0.492230	0.6153158
FERT	1	57.702	57.7025	0.884181	0.3533260
HARV	2	138.373	69.1864	1.060150	0.3569697
COLLECTION:FERT	2	1001.609	500.8046	7.673883	0.0016752
COLLECTION:HARV	4	227.226	56.8065	0.870452	0.4910869
FERT:HARV	2	48.241	24.1207	0.369604	0.6935999
COLLECTION:FERT:HARV	4	146.750	36.6876	0.562168	0.6915848
Residuals	36	2349.393	65.2609		

5.2: COLLECTIONS AT TARAWERA

Tarawera Litterfall Mass per Day Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0512441	0.05124411	1.181059	0.2914801
HARV	2	0.1374691	0.06873457	1.584173	0.2324182
FERT:HARV	2	0.1048770	0.05243848	1.208586	0.3217305
Residuals	18	0.7809892	0.04338829		

Tarawera Litterfall Carbon Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	1.252502	1.252502	12.43553	0.0024111
HARV	2	0.282479	0.141239	1.40230	0.2716548
FERT:HARV	2	0.276720	0.138360	1.37371	0.2784674
Residuals	18	1.812953	0.100720		

Tarawera Litterfall Nitrogen Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0091193	0.00911929	0.8816203	0.3601881
HARV	2	0.0028461	0.00142307	0.1375770	0.8723749
FERT:HARV	2	0.0147794	0.00738971	0.7144104	0.5028455
Residuals	18	0.1861881	0.01034378		

Tarawera Litterfall Carbon:Nitrogen Ratio Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	248.739	248.7390	1.676157	0.2117983
HARV	2	61.752	30.8761	0.208062	0.8140824
FERT:HARV	2	361.086	180.5428	1.216609	0.3194638
Residuals	18	2671.172	148.3984		

Tarawera Litterfall Mass per Day Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.1058998	0.1058998	2.330723	0.1442233
HARV	2	0.0275484	0.0137742	0.303153	0.7421832
FERT:HARV	2	0.0171411	0.0085706	0.188627	0.8297110
Residuals	18	0.8178564	0.0454365		

Tarawera Litterfall Carbon Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.066024	0.0660241	0.4148259	0.5276527
HARV	2	0.163750	0.0818749	0.5144153	0.6063783
FERT:HARV	2	0.136255	0.0681275	0.4280412	0.6582477
Residuals	18	2.864898	0.1591610		

Tarawera Litterfall Nitrogen Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0229375	0.02293755	4.066779	0.0589049
HARV	2	0.0075931	0.00379654	0.673118	0.5224974
FERT:HARV	2	0.0022581	0.00112904	0.200176	0.8203843
Residuals	18	0.1015241	0.00564023		

COLLECTIONS AT TARAWERA continued

Tarawera Litterfall Carbon:Nitrogen Ratio Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	459.505	459.5046	5.003518	0.0381894
HARV	2	81.890	40.9449	0.445847	0.6471641
FERT:HARV	2	50.888	25.4439	0.277057	0.7611855
Residuals	18	1653.053	91.8363		

Tarawera Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.652689	0.6526894	14.69611	0.0004886
FERT	1	0.152238	0.1522384	3.42784	0.0723227
HARV	2	0.141075	0.0705376	1.58824	0.2182662
COLLECTION:FERT	1	0.004906	0.0049055	0.11045	0.7415550
COLLECTION:HARV	2	0.023942	0.0119711	0.26954	0.7652546
FERT:HARV	2	0.090211	0.0451053	1.01560	0.3723261
COLLECTION:FERT:HARV	2	0.031807	0.0159037	0.35809	0.7014705
Residuals	36	1.598846	0.0444124		

Tarawera Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	30.67375	30.67375	236.0603	0.0000000
FERT	1	0.37170	0.37170	2.8605	0.0994198
HARV	2	0.15199	0.07599	0.5848	0.5624030
COLLECTION:FERT	1	0.94683	0.94683	7.2867	0.0105143
COLLECTION:HARV	2	0.29424	0.14712	1.1322	0.3335267
FERT:HARV	2	0.36695	0.18348	1.4120	0.2568267
COLLECTION:FERT:HARV	2	0.04602	0.02301	0.1771	0.8384260
Residuals	36	4.67785	0.12994		

Tarawera Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.0166821	0.01668210	2.087349	0.1571721
FERT	1	0.0304913	0.03049127	3.815222	0.0585953
HARV	2	0.0064338	0.00321692	0.402518	0.6716062
COLLECTION:FERT	1	0.0015656	0.00156557	0.195891	0.6607058
COLLECTION:HARV	2	0.0040054	0.00200268	0.250586	0.7796911
FERT:HARV	2	0.0058212	0.00291059	0.364188	0.6972909
COLLECTION:FERT:HARV	2	0.0112163	0.00560815	0.701721	0.5023854
Residuals	36	0.2877122	0.00799200		

Tarawera Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	45.402	45.4016	0.377977	0.5425548
FERT	1	692.200	692.1998	5.762696	0.0216631
HARV	2	23.786	11.8928	0.099010	0.9059794
COLLECTION:FERT	1	16.044	16.0438	0.133568	0.7168997
COLLECTION:HARV	2	119.856	59.9282	0.498914	0.6113261
FERT:HARV	2	191.465	95.7323	0.796990	0.4584749
COLLECTION:FERT:HARV	2	220.509	110.2544	0.917889	0.4085046
Residuals	36	4324.225	120.1174		

5.3: COLLECTIONS AT BERWICK

Berwick Litterfall Mass per Day Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.263412	0.2634124	0.7755522	0.3958004
HARV	1	0.095287	0.0952870	0.2805488	0.6060027
FERT:HARV	1	0.019243	0.0192427	0.0566552	0.8158785
Residuals	12	4.075739	0.3396449		

Berwick Litterfall Carbon Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.8328919	0.8328919	10.30556	0.0074891
HARV	1	0.0099313	0.0099313	0.12288	0.7320054
FERT:HARV	1	0.0397250	0.0397250	0.49153	0.4966183
Residuals	12	0.9698363	0.0808197		

Berwick Litterfall Nitrogen Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.05001787	0.05001787	7.541214	0.0177290
HARV	1	0.02097122	0.02097122	3.161839	0.1007038
FERT:HARV	1	0.00041201	0.00041201	0.062119	0.8073918
Residuals	12	0.07959122	0.00663260		

Berwick Litterfall Carbon:Nitrogen Ratio Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	262.7392	262.7392	7.172777	0.0201036
HARV	1	129.5754	129.5754	3.537408	0.0844809
FERT:HARV	1	3.5072	3.5072	0.095745	0.7623033
Residuals	12	439.5606	36.6301		

Berwick Litterfall Mass per Day Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.463441	0.4634410	1.854438	0.1982865
HARV	1	0.628468	0.6284677	2.514785	0.1387683
FERT:HARV	1	0.148057	0.1480567	0.592442	0.4563610
Residuals	12	2.998909	0.2499091		

Berwick Litterfall Carbon Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.364513	0.3645132	1.021588	0.3320892
HARV	1	0.008930	0.0089304	0.025028	0.8769277
FERT:HARV	1	0.089550	0.0895498	0.250973	0.6254533
Residuals	12	4.281724	0.3568104		

Berwick Litterfall Nitrogen Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0005324	0.00053240	0.0413929	0.8421906
HARV	1	0.0072559	0.00725586	0.5641271	0.4670764
FERT:HARV	1	0.0028817	0.00288168	0.2240443	0.6444698
Residuals	12	0.1543451	0.01286209		

Berwick Litterfall Carbon:Nitrogen Ratio Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	11.811	11.8112	0.1042425	0.7523530
HARV	1	67.486	67.4861	0.5956150	0.4551861
FERT:HARV	1	5.487	5.4869	0.0484259	0.8295245
Residuals	12	1359.659	113.3049		

Berwick Litterfall Mass per Day Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.082101	0.0821007	0.608001	0.4506471
HARV	1	0.195562	0.1955616	1.448242	0.2520144
FERT:HARV	1	0.038300	0.0382996	0.283630	0.6040541
Residuals	12	1.620406	0.1350338		

Berwick Litterfall Carbon Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.509798	0.5097984	5.219211	0.0413362
HARV	1	0.017227	0.0172274	0.176371	0.6819324
FERT:HARV	1	0.028224	0.0282241	0.288952	0.6007194
Residuals	12	1.172127	0.0976773		

Berwick Litterfall Nitrogen Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0677262	0.06772616	6.318694	0.0272222
HARV	1	0.0290592	0.02905917	2.711153	0.1255673
FERT:HARV	1	0.0001170	0.00011697	0.010913	0.9185274
Residuals	12	0.1286206	0.01071838		

Berwick Litterfall Carbon:Nitrogen Ratio Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	290.5720	290.5720	5.884795	0.0319734
HARV	1	149.7437	149.7437	3.032678	0.1071527
FERT:HARV	1	0.0256	0.0256	0.000519	0.9821993
Residuals	12	592.5208	49.3767		

Berwick Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	2.718314	1.359157	5.627296	0.0074723
FERT	1	0.730661	0.730661	3.025143	0.0905285
HARV	1	0.794305	0.794305	3.288647	0.0781041
COLLECTION:FERT	2	0.078293	0.039147	0.162078	0.8509915
COLLECTION:HARV	2	0.125012	0.062506	0.258792	0.7734074
FERT:HARV	1	0.000845	0.000845	0.003500	0.9531499
COLLECTION:FERT:HARV	2	0.204754	0.102377	0.423869	0.6577336
Residuals	36	8.695055	0.241529		

COLLECTIONS AT BERWICK continued

Berwick Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	1.195268	0.597634	3.349294	0.0463449
FERT	1	1.658198	1.658198	9.292970	0.0042943
HARV	1	0.035297	0.035297	0.197815	0.6591533
COLLECTION:FERT	2	0.049005	0.024503	0.137319	0.8721469
COLLECTION:HARV	2	0.000792	0.000396	0.002219	0.9977836
FERT:HARV	1	0.036423	0.036423	0.204125	0.6541219
COLLECTION:FERT:HARV	2	0.121076	0.060538	0.339269	0.7145433
Residuals	36	6.423688	0.178436		

Berwick Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	0.1199931	0.05999653	5.957341	0.0058212
FERT	1	0.0707836	0.07078364	7.028444	0.0118504
HARV	1	0.0534569	0.05345694	5.307994	0.0271093
COLLECTION:FERT	2	0.0474928	0.02374640	2.357893	0.1090722
COLLECTION:HARV	2	0.0038293	0.00191465	0.190115	0.8276887
FERT:HARV	1	0.0013299	0.00132991	0.132053	0.7184378
COLLECTION:FERT:HARV	2	0.0020807	0.00104037	0.103304	0.9021195
Residuals	36	0.3625569	0.01007103		

Berwick Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	781.772	390.8862	5.883542	0.0061536
FERT	1	296.384	296.3842	4.461116	0.0416794
HARV	1	337.824	337.8244	5.084866	0.0303125
COLLECTION:FERT	2	268.738	134.3691	2.022496	0.1470879
COLLECTION:HARV	2	8.981	4.4904	0.067589	0.9347629
FERT:HARV	1	6.381	6.3809	0.096044	0.7584168
COLLECTION:FERT:HARV	2	2.639	1.3194	0.019859	0.9803473
Residuals	36	2391.740	66.4372		

5.4: COLLECTIONS AT BURNHAM

Burnham Litterfall Mass per Day Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.561407	0.5614068	5.471702	0.0374422
HARV	1	0.019478	0.0194777	0.189838	0.6707862
FERT:HARV	1	0.249355	0.2493546	2.430313	0.1449802
Residuals	12	1.231222	0.1026019		

Burnham Litterfall Carbon Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0832096	0.08320959	1.522166	0.2409109
HARV	1	0.0687840	0.06878404	1.258277	0.2839223
FERT:HARV	1	0.0687660	0.06876603	1.257947	0.2839824
Residuals	12	0.6559832	0.05466527		

Burnham Litterfall Nitrogen Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.3512230	0.3512230	19.25050	0.0008845
HARV	1	0.0047872	0.0047872	0.26239	0.6177817
FERT:HARV	1	0.0208021	0.0208021	1.14016	0.3066288
Residuals	12	0.2189385	0.0182449		

Burnham Litterfall Carbon:Nitrogen Ratio Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	2261.756	2261.756	19.09166	0.0009131
HARV	1	0.061	0.061	0.00051	0.9823302
FERT:HARV	1	114.675	114.675	0.96798	0.3446059
Residuals	12	1421.619	118.468		

Burnham Litterfall Mass per Day Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.081881	0.08188057	0.8268432	0.3810877
HARV	1	0.000008	0.00000773	0.0000780	0.9930968
FERT:HARV	1	0.007689	0.00768890	0.0776438	0.7852599
Residuals	12	1.188335	0.09902794		

Burnham Litterfall Carbon Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0063195	0.0063195	0.11726	0.7379475
HARV	1	0.0404294	0.0404294	0.75018	0.4034035
FERT:HARV	1	0.5491009	0.5491009	10.18878	0.0077469
Residuals	12	0.6467124	0.0538927		

Burnham Litterfall Nitrogen Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.02401065	0.02401065	4.121096	0.0651229
HARV	1	0.00050970	0.00050970	0.087482	0.7724586
FERT:HARV	1	0.02411209	0.02411209	4.138506	0.0646333
Residuals	12	0.06991534	0.00582628		

COLLECTIONS AT BURNHAM continued

Burnham Litterfall Carbon:Nitrogen Ratio Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	189.9828	189.9828	4.354613	0.0589117
HARV	1	0.0230	0.0230	0.000526	0.9820764
FERT:HARV	1	202.8978	202.8978	4.650638	0.0520326
Residuals	12	523.5353	43.6279		

Burnham Litterfall Mass per Day Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.088301	0.0883007	0.362614	0.5582650
HARV	1	0.439334	0.4393338	1.804160	0.2040624
FERT:HARV	1	0.585454	0.5854542	2.404215	0.1469697
Residuals	12	2.922138	0.2435115		

Burnham Litterfall Carbon Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.254017	0.2540167	2.220280	0.1620167
HARV	1	0.004658	0.0046580	0.040714	0.8434705
FERT:HARV	1	0.943322	0.9433220	8.245282	0.0140517
Residuals	12	1.372890	0.1144075		

Burnham Litterfall Nitrogen Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.1559499	0.1559499	28.42681	0.00017886
HARV	1	0.0376719	0.0376719	6.86689	0.02236530
FERT:HARV	1	0.0489217	0.0489217	8.91753	0.01135370
Residuals	12	0.0658322	0.0054860		

Burnham Litterfall Carbon:Nitrogen Ratio Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	533.9372	533.9372	28.93337	0.00016563
HARV	1	86.6188	86.6188	4.69376	0.05111304
FERT:HARV	1	166.9614	166.9614	9.04743	0.01090553
Residuals	12	221.4483	18.4540		

Burnham Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	0.857514	0.4287571	2.889580	0.0685757
FERT	1	0.591917	0.5919170	3.989184	0.0533945
HARV	1	0.213123	0.2131228	1.436327	0.2385650
COLLECTION:FERT	2	0.139671	0.0698356	0.470652	0.6283838
COLLECTION:HARV	2	0.245696	0.1228482	0.827927	0.4451024
FERT:HARV	1	0.461633	0.4616332	3.111146	0.0862439
COLLECTION:FERT:HARV	2	0.380864	0.1904322	1.283405	0.2894663
Residuals	36	5.341696	0.1483804		

Burnham Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	1.026940	0.5134699	6.908737	0.0028878
FERT	1	0.253436	0.2534362	3.409984	0.0730368
HARV	1	0.005585	0.0055854	0.075152	0.7855450
COLLECTION:FERT	2	0.090110	0.0450548	0.606212	0.5508859
COLLECTION:HARV	2	0.108286	0.0541430	0.728494	0.4896137
FERT:HARV	1	0.080841	0.0808413	1.087719	0.3039305
COLLECTION:FERT:HARV	2	1.480348	0.7401738	9.959038	0.0003610
Residuals	36	2.675586	0.0743218		

Burnham Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	0.1813526	0.0906763	9.20348	0.0005911
FERT	1	0.4351016	0.4351016	44.16204	0.0000001
HARV	1	0.0193131	0.0193131	1.96024	0.1700470
COLLECTION:FERT	2	0.0960820	0.0480410	4.87607	0.0133671
COLLECTION:HARV	2	0.0236557	0.0118279	1.20051	0.3128074
FERT:HARV	1	0.0147184	0.0147184	1.49389	0.2295567
COLLECTION:FERT:HARV	2	0.0791175	0.0395588	4.01514	0.0266635
Residuals	36	0.3546860	0.0098524		

Burnham Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	2	938.525	469.263	7.79721	0.0015367
FERT	1	2377.179	2377.179	39.49890	0.0000003
HARV	1	29.463	29.463	0.48955	0.4886233
COLLECTION:FERT	2	608.497	304.248	5.05535	0.0116148
COLLECTION:HARV	2	57.239	28.620	0.47554	0.6253976
FERT:HARV	1	29.364	29.364	0.48791	0.4893476
COLLECTION:FERT:HARV	2	455.170	227.585	3.78152	0.0323085
Residuals	36	2166.603	60.183		

5.5: COLLECTIONS AT KINLEITH

Kinleith Litterfall Mass per Day Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0237066	0.02370658	0.6649126	0.4254898
HARV	2	0.0064258	0.00321290	0.0901141	0.9142365
FERT:HARV	2	0.0383836	0.01919178	0.5382834	0.5928579
Residuals	18	0.6417661	0.03565367		

Kinleith Litterfall Carbon Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.82811	0.828108	0.7496805	0.3979715
HARV	2	0.57808	0.289039	0.2616653	0.7726465
FERT:HARV	2	0.18280	0.091399	0.0827426	0.9209361
Residuals	18	19.88305	1.104614		

Kinleith Litterfall Nitrogen Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0086124	0.00861236	0.294958	0.5937230
HARV	2	0.0605387	0.03026935	1.036672	0.3748652
FERT:HARV	2	0.0114222	0.00571111	0.195596	0.8240695
Residuals	18	0.5255745	0.02919858		

Kinleith Litterfall Carbon:Nitrogen Ratio Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	28.574	28.5744	0.267192	0.6115149
HARV	2	294.352	147.1761	1.376207	0.2778658
FERT:HARV	2	94.067	47.0334	0.439797	0.6509064
Residuals	18	1924.979	106.9433		

Kinleith Litterfall Mass per Day Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.1073025	0.1073025	3.200446	0.0904603
HARV	2	0.0669324	0.0334662	0.998176	0.3880571
FERT:HARV	2	0.0309817	0.0154908	0.462036	0.6372669
Residuals	18	0.6034926	0.0335274		

Kinleith Litterfall Carbon Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.010746	0.0107459	0.0538216	0.8191591
HARV	2	0.043319	0.0216596	0.1084839	0.8977755
FERT:HARV	2	0.053841	0.0269206	0.1348345	0.8747349
Residuals	18	3.593824	0.1996569		

Kinleith Litterfall Nitrogen Content Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0578699	0.05786987	1.744445	0.2031235
HARV	2	0.0672401	0.03362005	1.013452	0.3827616
FERT:HARV	2	0.0045759	0.00228796	0.068969	0.9336011
Residuals	18	0.5971285	0.03317381		

Kinleith Litterfall Carbon:Nitrogen Ratio Collection Three

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	219.966	219.9661	2.219780	0.1535667
HARV	2	179.584	89.7919	0.906132	0.4217407
FERT:HARV	2	22.256	11.1280	0.112298	0.8943995
Residuals	18	1783.685	99.0936		

Kinleith Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.360104	0.3601040	10.41048	0.0026692
FERT	1	0.115940	0.1159404	3.35180	0.0754193
HARV	2	0.050436	0.0252178	0.72904	0.4893576
COLLECTION:FERT	1	0.015069	0.0150687	0.43563	0.5134398
COLLECTION:HARV	2	0.022923	0.0114613	0.33134	0.7201261
FERT:HARV	2	0.062619	0.0313095	0.90515	0.4134892
COLLECTION:FERT:HARV	2	0.006746	0.0033731	0.09752	0.9073269
Residuals	36	1.245259	0.0345905		

Kinleith Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.48155	0.4815483	0.7384176	0.3958544
FERT	1	0.51376	0.5137598	0.7878115	0.3806545
HARV	2	0.25188	0.1259424	0.1931230	0.8252290
COLLECTION:FERT	1	0.32509	0.3250936	0.4985063	0.4847016
COLLECTION:HARV	2	0.36951	0.1847563	0.2833098	0.7549503
FERT:HARV	2	0.06818	0.0340913	0.0522765	0.9491384
COLLECTION:FERT:HARV	2	0.16846	0.0842280	0.1291572	0.8792412
Residuals	36	23.47688	0.6521355		

Kinleith Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.005020	0.00501982	0.160963	0.6906431
FERT	1	0.055566	0.05556590	1.781747	0.1903158
HARV	2	0.127191	0.06359568	2.039225	0.1448933
COLLECTION:FERT	1	0.010916	0.01091633	0.350037	0.5577894
COLLECTION:HARV	2	0.000587	0.00029372	0.009418	0.9906284
FERT:HARV	2	0.015229	0.00761430	0.244156	0.7846519
COLLECTION:FERT:HARV	2	0.000770	0.00038477	0.012338	0.9877421
Residuals	36	1.122703	0.03118620		

COLLECTIONS AT KINLEITH continued

Kinleith Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	9.331	9.3312	0.090578	0.7651751
FERT	1	203.551	203.5507	1.975866	0.1683988
HARV	2	461.567	230.7836	2.240216	0.1210689
COLLECTION:FERT	1	44.990	44.9897	0.436715	0.5129191
COLLECTION:HARV	2	12.369	6.1844	0.060032	0.9418288
FERT:HARV	2	98.188	49.0942	0.476558	0.6247783
COLLECTION:FERT:HARV	2	18.134	9.0671	0.088014	0.9159441
Residuals	36	3708.664	103.0185		

5.6: COLLECTIONS AT GOLDEN DOWNS

Golden Downs Litterfall Mass per Day Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.101458	0.1014583	1.489299	0.2380726
HARV	2	0.154221	0.0771104	1.131898	0.3443223
FERT:HARV	2	0.041775	0.0208877	0.306609	0.7397064
Residuals	18	1.226248	0.0681249		

Golden Downs Litterfall Carbon Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.168636	0.1686364	0.431981	0.5193351
HARV	2	0.724939	0.3624695	0.928506	0.4132639
FERT:HARV	2	1.234781	0.6173905	1.581515	0.2329443
Residuals	18	7.026827	0.3903793		

Golden Downs Litterfall Nitrogen Content Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0085450	0.00854501	0.4743539	0.4997727
HARV	2	0.0144437	0.00722185	0.4009022	0.6755489
FERT:HARV	2	0.0086378	0.00431888	0.2397513	0.7892963
Residuals	18	0.3242519	0.01801400		

Golden Downs Litterfall Carbon:Nitrogen Ratio Collection One

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	215.765	215.7654	1.171903	0.2932999
HARV	2	127.974	63.9869	0.347537	0.7110625
FERT:HARV	2	89.728	44.8639	0.243673	0.7862878
Residuals	18	3314.076	184.1154		

Golden Downs Litterfall Mass per Day Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.040213	0.04021291	0.5049187	0.4864525
HARV	2	0.046813	0.02340642	0.2938942	0.7488642
FERT:HARV	2	0.023809	0.01190437	0.1494729	0.8622196
Residuals	18	1.433562	0.07964233		

Golden Downs Litterfall Carbon Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.543564	0.543564	1.272841	0.2740481
HARV	2	4.299253	2.149626	5.033694	0.0183499
FERT:HARV	2	1.242034	0.621017	1.454211	0.2597535
Residuals	18	7.686855	0.427047		

Golden Downs Litterfall Nitrogen Content Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	0.0044933	0.00449335	0.453932	0.5090336
HARV	2	0.0074556	0.00372781	0.376595	0.6914744
FERT:HARV	2	0.0239449	0.01197243	1.209492	0.3214738
Residuals	18	0.1781772	0.00989873		

COLLECTIONS AT GOLDEN DOWNS continued

Golden Downs Litterfall Carbon:Nitrogen Ratio Collection Two

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
FERT	1	69.771	69.7708	0.859868	0.3660434
HARV	2	24.913	12.4563	0.153514	0.8587998
FERT:HARV	2	263.121	131.5606	1.621377	0.2251931
Residuals	18	1460.543	81.1413		

Golden Downs Litterfall Mass per Day All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.252599	0.2525993	3.418881	0.0726799
FERT	1	0.006961	0.0069612	0.094219	0.7606489
HARV	2	0.060149	0.0300745	0.407052	0.6686344
COLLECTION:FERT	1	0.134710	0.1347100	1.823273	0.1853526
COLLECTION:HARV	2	0.140885	0.0704424	0.953424	0.3949363
FERT:HARV	2	0.008374	0.0041870	0.056670	0.9449895
COLLECTION:FERT:HARV	2	0.057210	0.0286051	0.387164	0.6817728
Residuals	36	2.659810	0.0738836		

Golden Downs Litterfall Carbon Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	16.55343	16.55343	40.50132	0.0000002
FERT	1	0.05334	0.05334	0.13050	0.7200225
HARV	2	4.01669	2.00834	4.91382	0.0129763
COLLECTION:FERT	1	0.65886	0.65886	1.61204	0.2123518
COLLECTION:HARV	2	1.00750	0.50375	1.23253	0.3035629
FERT:HARV	2	0.92188	0.46094	1.12779	0.3349195
COLLECTION:FERT:HARV	2	1.55493	0.77747	1.90223	0.1639360
Residuals	36	14.71368	0.40871		

Golden Downs Litterfall Nitrogen Content All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	0.0256026	0.02560261	1.834476	0.1840404
FERT	1	0.0003228	0.00032275	0.023126	0.8799795
HARV	2	0.0132228	0.00661138	0.473718	0.6265093
COLLECTION:FERT	1	0.0127156	0.01271561	0.911097	0.3461892
COLLECTION:HARV	2	0.0086766	0.00433828	0.310846	0.7347736
FERT:HARV	2	0.0303184	0.01515922	1.086187	0.3483053
COLLECTION:FERT:HARV	2	0.0022642	0.00113210	0.081117	0.9222541
Residuals	36	0.5024291	0.01395636		

Golden Downs Litterfall Carbon:Nitrogen Ratio All Collections

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
COLLECTION	1	168.922	168.9218	1.273648	0.2665484
FERT	1	20.073	20.0729	0.151347	0.6995433
HARV	2	79.384	39.6918	0.299271	0.7431848
COLLECTION:FERT	1	265.463	265.4633	2.001559	0.1657294
COLLECTION:HARV	2	73.503	36.7514	0.277101	0.7595800
FERT:HARV	2	321.380	160.6902	1.211583	0.3095767
COLLECTION:FERT:HARV	2	31.469	15.7343	0.118634	0.8884782
Residuals	36	4774.620	132.6283		

STATISTICAL APPENDIX SIX: 300 INDEX ANOVA Outputs

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Woodhill 300 Index
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1  92.29880 92.29880 41.14450 0.0000333
     HARV  2   7.05823  3.52911  1.57319 0.2473057
FERT:HARV  2   1.30544  0.65272  0.29097 0.7526683
Residuals 12  26.91941  2.24328

Tarawera 300 Index
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   4.14067 4.140666 2.174950 0.1575507
     HARV  2   2.18922 1.094611 0.574962 0.5727289
FERT:HARV  2   0.10595 0.052974 0.027826 0.9725997
Residuals 18  34.26837 1.903798

Berwick 300 Index
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
     FERT  1   1.16578 1.165778 0.2292350 0.6406974
     HARV  1   1.68791 1.687906 0.3319046 0.5751859
FERT:HARV  1   1.04667 1.046675 0.2058149 0.6581628
Residuals 12  61.02618 5.085515

Burnham 300 Index
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
     FERT  1  0.100383 0.1003835 0.306694 0.5898867
     HARV  1  0.016696 0.0166956 0.051009 0.8251181
FERT:HARV  1  0.805327 0.8053266 2.460450 0.1427246
Residuals 12  3.927703 0.3273086

Kinleith 300 Index
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   4.17013 4.170126 2.020383 0.1722946
     HARV  2  15.32829 7.664147 3.713200 0.0446569
FERT:HARV  2   5.59507 2.797535 1.355377 0.2829368
Residuals 18  37.15249 2.064027

Golden Downs 300 Index
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
     FERT  1   3.93737 3.937367 2.143601 0.1604118
     HARV  2   3.91417 1.957086 1.065487 0.3653168
FERT:HARV  2   0.97394 0.486972 0.265120 0.7700577
Residuals 18  33.06241 1.836801

All Sites Combined 300 Index
           Df Sum of Sq  Mean Sq  F Value         Pr(F)
     SITE   5  447.4243 89.48487 41.64139 0.00000000000
     FERT   1   37.2383 37.23833 17.32869 0.00006267765
SITE:FERT   5   68.5748 13.71496  6.38220 0.00003051931
Residuals 110  236.3835  2.14894

WT and SO Treatment Plots at All Sites Combined 300 Index
               Df Sum of Sq  Mean Sq  F Value     Pr(F)
          SITE  5  271.9692 54.39383 22.35543 0.0000000
          FERT  1   17.4551 17.45505  7.17389 0.0092672
          HARV  1    0.0504  0.05035  0.02070 0.8860380
     SITE:FERT  5   43.5294  8.70589  3.57805 0.0062358
     SITE:HARV  5   13.0024  2.60047  1.06877 0.3854325
     FERT:HARV  1    0.0706  0.07061  0.02902 0.8652342
SITE:FERT:HARV  5    8.1593  1.63187  0.67068 0.6470109
     Residuals 68  165.4533  2.43314

Woodhill, Tarawera, Kinleith and Golden Downs Combined 300 Index
               Df Sum of Sq  Mean Sq  F Value     Pr(F)
          SITE  3  391.3403 130.4468 65.51988 0.0000000
          FERT  1   55.1527  55.1527 27.70172 0.0000017
          HARV  2   13.4853   6.7427  3.38666 0.0397987
     SITE:FERT  3   49.3942  16.4647  8.26979 0.0000950
     SITE:HARV  6   15.0046   2.5008  1.25607 0.2898183
     FERT:HARV  2    2.4835   1.2417  0.62369 0.5390932
SITE:FERT:HARV  6    5.4969   0.9162  0.46016 0.8352284
     Residuals 66  131.4027   1.9909
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